RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

VOLUME LXIV.

Published by order of the Government of India.

CALCUTTA: GOVERNMENT OF INDIA
CENTRAL PUBLICATION BRANCH
1930

PREFACE.

THE first Review of the Mineral Production of India, published by the Geological Survey, appeared in Part I of Volume XXXIII of the Records. In preparing it, the Director, Sir Thomas Holland, designed the general plan of the work and surveyed the progress made during the preceding six years (1898-1903). Subsequent issues, covering the periods 1904-1908, 1909-1913, 1914-1918 and 1919-1923, followed the same general scheme, but were purposely made more descriptive. The reason for this in the earlier reviews was the fact that Ball's Manual on Economic Geology had long been out of print. Mr. LaTouche's Bibliography of Indian Geology and Physical Geography, with its Annotated Index of Minerals of Economic Value, published within the last twelve years, has taken the place of Ball's Manual, and the descriptive parts of the Quinquennial Review might, therefore, be now thought unnecessary. It is considered, however, that the descriptive matter, so long as it is kept within bounds, not only makes a more connected narrative and ensures a truer interpretation of mere statistics, but provides an opportunity of drawing attention to crucial geological facts pertaining to new discoveries.

The present review, instead of being reduced, has, in fact, been slightly expanded, and, for the sake of ready reference, includes matter which has been published before. It is the sixth of the series, and has been prepared on the same lines as the last by the collaboration of the senior officers of the Geological Survey, who have individually revised the sections committed to their charge. The name of the officer responsible for the revision of each section is shown in the text. The general plan has been retained, and in many cases the descriptive parts have also remained much the same as they were when originally written. Recent additions to our information have, of course, been inserted and figures and statistics brought up to date.

E. H. PASCOE.

The 18th December 1929.

RECORDS

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THE GEOLOGICAL SURVEY OF INDIA.

Vol. LXIV.] 1930 [October.

QUINQUENNIAL REVIEW OF THE MINERAL PRODUCTION OF INDIA FOR THE YEARS 1924 TO 1928. *By the Director and Senior Officers of the Geological Survey of India.*

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I.—INTRODUCTION.

[E. H. PASCOE.]

In the first Review it was explained that, although many valuable mineral products were being worked in different parts of the country, it was impossible to obtain figures relating to some of them sufficiently precise to be of any value for statistical purposes. The most conspicuous of these 'minerals'- classified as such for convenience sake—are the various forms of building material and slate, which are naturally used extensively in every district and would form an excellent index of material progress, if reliance could be placed on the figures returned and if the figures of one period could be regarded as fairly comparable with those of another.

Grouping of the minerals.

In order to obtain some mental impression of progress, we are compelled to exclude from the list of minerals contributing to the statement of total values, those about which we can obtain only partial figures or rough local estimates. The minerals are thus reviewed in two groups, as before, namely:—

Group I.—Those for which approximately trustworthy annual returns are obtainable; and

Group II.—Those regarding which regularly recurring and full particulars cannot be procured.

As the methods of collecting the returns become more precise from year to year and the machinery employed for the purpose becomes more efficient, the minerals included in Group I tend to increase in number; that group now comprises:—

Antimony.	Iron.
Chromite.	Jadeite.
Coal.	Lead.
Copper.	Magnesite.
Diamonds.	Manganese.
Gold.	Mica.
Graphite.	Monazite.
Ilmenite.	Nickel.

Petroleum.	Tin.
Ruby, Sapphire and Spinel.	Tungsten.
Salt.	Zinc.
Saltpetre.	Zircon.
Silver.	

Units recognised.

Unless otherwise stated, the ton referred to in this review is the English statute ton of 2,240 lbs. Where there are totals likely to be of interest to foreign readers, weights are also expressed in metric tons of 1,000 kilogrammes each (equal to 0·984 statute ton). Returns in *maunds*[1] have been translated into tons, hundredweights and quarters throughout. The output of petroleum has been given in Imperial gallons, and totals are expressed also in metric tons, on the assumption that one metric ton is equivalent to 249 gallons of crude oil of an average specific gravity of 0·885. Values in sterling are calculated throughout at the approximate average rate of exchange for the particular year; this rate of exchange is indicated in each case.

Sources of information.

The data employed in this review have been obtained from various sources. Before the year 1904 the Annual Statistics of Mineral Production were published by the Director-General of Statistics. Since then the figures of mineral production for India have been published annually in the Records of the Geological Survey of India. Returns of mineral production are now sent by Local Governments, Political Agents and in a few cases by Indian Durbars, direct to the Director of the Geological Survey, except in the case of mines under the Mines Act, when the figures are forwarded direct by mine-managers to the Chief Inspector of Mines, who forwards a summary to the Geological Survey. Information regarding exports and imports has been derived from the publications issued by the Director General of Commercial Intelligence and Statistics, whose co-operation in other ways has also been of great assistance. Additional information has been obtained from the following sources:—

(1) Annual Returns of the Chief Inspector of Mines in India, and the Chief Inspector of Mines for Mysore;

(2) Annual Administration Reports of the various Local Governments and Local Administrations in India;

[1] One *maund*=82·3 lbs.

(3) Annual Administration Reports of the Railway Board;
(4) Returns issued by the various Geological Surveys and Statistics relating to Mines and Quarries, published by the English Home Office.
(5) Reports by the Imperial Institute, London.

We are also indebted to the Managing Agents of several Mining Companies for much information supplied direct.

II.—SUMMARY OF PROGRESS.

[E. H. PASCOE.]

Values.

Table I summarises the output and value of the principal minerals produced during the five years under review. The total values have the obvious defect of being the addition of unlike denominations. This applies much more markedly to the previous quinquennium, during which the exchange varied between the wide limits of 1*s.* $2\frac{15}{16}$*d.* and 2*s.* $10\frac{1}{2}$*d.* per rupee. Between 1921 and 1928, the exchange varied from 1*s.* $4\frac{1}{2}$*d.* to 1*s.* $6\frac{9}{32}$*d.* per rupee. This variation in exchange, small as it is compared with that of the previous five years, combined with a variation in the actual intrinsic value of the minerals and the enhanced effect caused by the lack of synchronism between the time of purchase and the time of payment, detract considerably from the precision of statistics. Furthermore, export values, being the only returns obtainable in some cases, are ranged with spot values, while the latter necessarily vary with the position of the mine, representing not the *values* but the *prices* obtainable. In the case of coal, for instance, the so-called value of a ton of good coal in Bengal is less than half that of the inferior material raised in Baluchistan; in the case of salt, the values given are the prices charged, and are less than the duty, which is the principal value of the salt to Government. Certain valuable mineral products, such as building stones, are omitted altogether for want of any but very approximate estimates.

The values returned for minerals exported are also necessarily lower than they would be if those minerals were consumed in the country, and it is consequently unfair to compare this table of values with corresponding returns for countries in which metallurgical industries flourish. Manganese-ore is a conspicuous example of a product the value of which, to the Indian producer, is reduced by the heavy cost of transport. The country is thus not only so much poorer by the loss of the metal exported in the ore, but is paid in return considerably less than its market value.

The imperfections of the table are not only those confessedly inseparable from all such estimates of mineral production, but are the lingering relics of the war, and more especially of the economic convulsions resulting therefrom. The value of comparison with other quinquennial periods is largely affected by the intervening period of the war, and comparison of the figures given in Table I with pre-war figures is likely to be misleading in individual cases. But the general trend of the Indian mineral industries is fairly clear, and the decrease made during the five years under review has not been very considerable, the estimated value of the total output being about $3\frac{1}{2}$ million pounds less than it was during the previous period. In the latter the average annual value of the output of minerals for which reliable statistics are available was over £24,600,000, while during 1924-28 it fell to nearly £23,900,000.

Comparison with the previous periods.

During the quinquennial period under review, the output of coal has slowly but steadily increased since 1925, but this increase has unfortunately been accompanied by an equally steady and noticeable drop in value. The output of petroleum has been steady, but a severe drop in the market price characterised the last two years of the period. The value of the manganese production showed a slight general increase. The decline in the output of gold recorded during the War period as a result of the rise in price of all ordinary commodities was repeated during the five years following and again during the period under review. There was a general increase in the production of lead, zinc and silver, which was marked in the first two; in the case of lead, this was not accompanied, however, by an increase in value. In 1926 there was a noticeable drop in the market value of silver. During the first four years there was a notable increase in the output and value of tin produced. The quantity and value of iron-ore showed a steady improvement and those of copper and copper-matte a large general increase. There was a heavy fall in the market price of magnesite in 1928. Ilmenite showed a marked general increase in quantity and value. There was a decline in the output and value of saltpetre. Salt production was moderately steady, while the output of mica, chromite, tungsten and magnesite was capricious.

Fluctuations in output and market price.

TABLE 1.—*Output and value of Minerals for which reliable returns of production are available for the years 1924-1928.*

Mineral.		1924. (£1 = Rs 13 9)	1925. (£1 = Rs. 13 3)	1926. (£1 = Rs. 13 4)	1927. (£1 = Rs. 13 4)	1928. (£1 = Rs. 13 4)	*Average.*
		£	£	£	£	£	£
Coal	£ tons	10,766,433 21,174,284	9,503,828 20,904,377	7,574,509 20,999,167	7,079,852 22,082,[illegible]	6,604,106 22,512,872	[illegible],764 21,540,607
Petroleum	£ gals	7,559,233 294,571,692	7,740,727 289,606,542	7,305,509 280,369,326	4,421,468 281,113,909	4,314,207 3[illegible]5,943,711	6,268,[illegible]29 290,321,036
Manganese-ore (a)	£ tons	2,500,157 706,449	2,211,181 738,851	1,489,052 613,536	2,019,264 813,821	1,874,32[illegible] 834,144	[illegible],018,805 7[illegible]9,360
Gold	£ oz.	1,827,433 396,3[illegible]1	1,673,501 393,875	1,624,[illegible]38 384,158	1,626,913 381,272	[illegible] 370,063	1,668,067 386,944
Lead and lead-ore	£ tons	1,67[illegible],652 73,068	1,64[illegible],477 46,647	1,666,587 53,679	1,641,0[illegible]5 66,124	1,642,036 78,294	[illegible] [illegible],622
Silver	£ oz.	810,869 5,309,20[illegible]	705,503 4,856,422	663,063 [illegible],126,088	708,846 6,021,806	802,400 7,425,810	[illegible],148 5,74[illegible],466
Salt	£ tons	7[illegible]0,717 1,6[illegible]3,476	574,028 1,295,144	836,830 1,638,74[illegible]	849,265 1,611,915	[illegible] [illegible]	[illegible]41,168 [illegible],912
Mica (b)	£ cwts	679,796 70,0[illegible]5	709,183 99,699	820,901 89,917	691,311 7[illegible],485	[illegible] [illegible]	737,930 86,542
Zinc concentrates	£ tons	161,784 15,650	152,325 10,810	171,977 48,831	[illegible] [illegible]	[illegible] [illegible]	376,31[illegible] 4[illegible],340
Tin and tin-ore	£ tons	208,179 1,880	267,931 2,308	455,362 3,548	4[illegible]3,804 3,495	338,[illegible] 2,780	3[illegible]2,846 2,802
Iron-ore	£ tons	279,610 1,445,313	336,775 1,[illegible]44,[illegible]78	349,676 1,659,295	380,735 1,840,[illegible]	413,010 2,0[illegible],992	351,371 1,710,383
Copper-ore and copper-matte.	£ tons	114,714 2,935	301,875 34,148	318,381 20,949	336,836 16,882	[illegible] 23,098	234,801 [illegible],830
Saltpetre (b)	£ cwts.	201,382 167,700	147,617 126,973	98,846 98,830	113,632 123,018	74,62[illegible] 89,670	1[illegible]7,221 1[illegible]1,216
Chromite	£ tons	42,259 4[illegible],462	40,171 37,452	30,810 83,382	6[illegible],713 67,207	[illegible] [illegible]	47,224 43,792
Tungsten-ore	£ tons	24,559 739	33,975 772	57,535 1,484	4[illegible],[illegible]37 1,160	[illegible] [illegible]	[illegible]6,192 9[illegible]
Jadeite (b)	£ cwts	50,849 2,708	12,237 972	35,0[illegible]1 2,139	22,[illegible]70 1,981	43,468 2,698	[illegible]2,843 2,107
Ruby, sapphire and spinel.	£ carats	34,773 101,097	27,454 149,037	34,884 105,671	20,833 39,590	13,[illegible]47 40,380	[illegible] [illegible]
Magnesite	£ tons	21,088 24,461	31,179 29,020	26,444 30,461	17,115 19,638	11,969 24,406	21,5[illegible]9 25,717
Antimonial lead and antimony ore.	£ tons	22,027 1,200	21,373 1,110	24,119 1,165	10,714 1,003	24,427 1,611	20,532 1,218
Ilmenite	£ cwts.	1,381 641	492 828	7,587 4,236	33,443 17,809	41,537 25,307	16,892 9,664
Nickel speiss	£ tons	.. ..	.. ..	.. ..	13,176 1,032	39,922 2,933	10,620 793
Zircon	£ tons	2,717 365	4,608 576	2,987 582	8,129 1,465	4,267 855	4,542 769
Monazite	£ tons	9,801 622	.. ..	947 64	8,810 280	1,242 103	3,060 214
Diamonds	£ carats	1,955 66	1,098 48	2,131 69	8,354 118	4,887 824	2,691 221
TOTAL VALUE	£	27,683,898	26,233,633	23,927,506	21,150,764	20,332,089	23,875,678

(a) Export value of quantities actually exported. (b) Export figures.

The stimulating effect of the War on metallurgical industries is still perceptible in certain directions. The activities in the output of the Tata Iron and Steel works at Jamshedpur, of the Bengal Iron Company at Kulti, and of the Indian Iron and Steel Company at Hirapur bear witness to this statement. The operations of the Burma Corporation at Bawdwin have also extended, and the output of lead, silver, zinc, copper and antimonial lead is making remarkable strides. Copper smelting was definitely established in Singhbhum during the previous five-year period, and has become a permanent industry of the district; copper-matte is also being produced in increasing quantities at Namtu in the Northern Shan States of Burma.

TABLE 2.—*Values (a) during 1927 of the twelve leading Mineral Products in the United Kingdom.*

Coal	183,544,218
Clay (including china and fire clays) and shale	3,620,373
Limestone and dolomite	[illegible],103,872
Iron-ore	5,240,172
Igneous rocks	3,2[illegible]2,481
Slate	2,372,[illegible]67
Sandstone (other than ganister and silica rocks)	1,762,255
Salt	1,335,964
Gravel and sand	831,770
Tin-ore	621,061
Oil shale	616,394
Chalk	449,267

(*a*) Value at mine or quarry.

Table 2 shows the values of the more important mineral products of the United Kingdom during the year 1927. The enormous preponderance of the coal industry in the United Kingdom is remarkable, although less than it was five years previously. Iron-ore, the next most important mineral product in the world excepting petroleum, takes the fourth place.

Imports of minerals and mineral products.

In this summary also it will be interesting to note the value recorded for imported minerals and for products obtained directly from minerals during the period under review. These figures, exclusive of the values of cutlery and hardware, machinery and millwork, railway plant and rolling stock, earthenware and porcelain, glass and glassware, jewellery and plate of gold and silver, paints and colours, and alizarine and aniline dyes, are shown in Table 3. The chief features, brought out by a comparison of this table with the corresponding table in the previous Review, are a general increase in the quantities imported accompanied by a general fall in prices.

The principal exceptions are those of iron, lead, quicksilver and—as far as price is concerned--tin. There was, for instance, an increase of over 12 per cent. in the average imports of salt accompanied by a conspicuous fall in the value; in 1919-23 the average cost per ton of imported salt was Rs. 35·4, while in 1924-28 it fell to Rs. 23·7. In the case of brass, we find an increase of the annual imports during the five years under consideration, averaging about 29·5 per cent. more than those of the previous five years; in spite of this, the total value for the five years 1924-28 was more than half a *lakh* less than the total for the previous period. The same story may be told respecting copper. In spite of the notable increase in the indigenous production of this metal India still imports well over 15,000 tons of copper a year. Nearly three times the quantity of German silver absorbed during 1919-23 was imported during 1924-28 at a considerably reduced cost. Zinc imports showed a large increase accompanied by a decline in price. In contrast with the above, imports of iron dropped to a little more than half of what they were in the previous period; there was at the same time a fall in the value. In the case of steel or 'iron or steel', however, there was a heavy increase in the quantities imported with a very noticeable fall in the price. There was a 34-per-cent. decrease in the imports of lead with scarcely any change in price. The imports of quicksilver showed a marked reduction in quantity and a small reduction in price. Most of the exports of tin concentrates go to the Straits Settlements and are imported again in the form of wrought tin; these imports shewed an increase accompanied by a rise in value. Imports of mineral oil rose, while those of coal and coke fell.

Table 4 is even more instructive. The remarkable fall in the value of the imports of railway material during the war period from nearly £10,000,000 in 1914 to a little over £500,000 in 1917 was eloquent of the difficulties that the railway companies had to face; the fall was due to difficulty in procuring those imports and not to any decreased demand. The effect, it was hoped, would make India more self-supporting and create industries that, in normal circumstances, might not have arisen for many years. A number of new engineering companies were stimulated into existence and the dividends paid by those already established rose to unprecedented amounts. Although this stimulus to the Indian industry proved in many cases to be ephemeral, it is gratifying to note that in 1924-28 the value of imports of railway plant and rolling stock averaged less than half what they did during the post-war

Table 3.—*Amount and value of Imports of minerals and products obtained directly from minerals for the years 1924 to 1928 (including Government stores).*

—		1924.	1925.	1926.	1927.	1928.	*Average*
Salt . .	Rs. tons	1,38,96,770 595,606	1,02,47,114 541,141	1,04,37,770 515,798	1,88,58,913 637,694	1,54,36,628 614,417	*1 37,74,439* *580,943*
Metals—							
Brass . .	Rs. cwts.	3,27,51,727 622,322	2,60,38,703 502,474	2,71,56,333 558,953	2,28,14,945 401,853	2,55,89,077 545,599	*2,68,70,167* *544,240*
Copper . .	Rs. cwts.	1,73,70,001 287,040	1,90,34,755 340,957	1,92,63,907 396,030	1,47,82,388 303,437	1,56,92,282 309,925	*1,72,28,865* *32[illegible],657*
German silver	Rs. cwts.	15,52,503 13,527	21,18,326 19,372	16,09,161 17,533	13,60,821 15,135	21,29,444 25,026	*17,54,111* *18,119*
Iron . .	Rs tons	32,46,182 18,001	28,96 335 17,775	23,12,530 13,503	25,16,034 19,155	20,75,394 14,657	*26,09,415* *16,678*
Iron or steel .	Rs. tons	16,68,06,548 682,369	15,47,92,396 668,920	16,63,32 509 738,950	18,25,16,326 871,813	18,81,48,943 1,013,458	*17,17,19,344* *795,102*
Steel . .	Rs. tons	3,56,87,206 256,549	1,79,31,685 117,788	2,41,14,554 228,455	2,76,83,218 260,389	2,66,84,083 250,954	*2,64,00,149* *223,827*
Lead . .	Rs cwts	15,53,284 52,564	16,73,667 52,187	17,47,314 51,865	13,31,534 50,019	9,34,515 44,742	*14,48,063* *50,875*
Quicksilver .	Rs. lbs.	8,51,140 166,370	5,47,094 240,552	6,33,625 243,879	6,07,671 195,830	8,90,757 243,708	*6,18,117* *218,065*
Tin . .	Rs. cwts.	85,05,323 55,260	1,06,15,181 61,550	1,01,44,177 54,584	1,28,84,826 66,527	94,77,631 57,855	*1,03 25,455* *59,155*
Zinc . .	Rs. cwts	29,46,564 115,361	38,24,572 145,142	51,22,679 192,730	41,72,974 181,999	36,59,370 188,885	*39,45,234* *164,823*
Unenumerated	Rs. cwts.	10,34,549 19,128	7,86,716 13,541	17,76,141 33,118	18,86,339 41,747	11,36,445 23,420	*13,24,038* *26,191*
Total value of metals	**Rs.**	**27,17,06,227**	**24,02,59,430**	**26,02,13,620**	**27,26,17,676**	**27,64,17,950**	**26,42,42,981**
Inorganic chemicals.	Rs.	2,19,15,574	2,04,69,170	2,42,10,736	2,71,78,634	2,67,68,433	*2,41,14,609*
Mineral oil .	Rs. gals.	9,09,23,391 183,418,098	9,41,92,304 186,173,244	9,25,19,247 191,549,190	10,47,31,110 220,519,985	10,40,57,237 237,252,128	*9,73 44,718* *203,781,129*
Paraffin . .	Rs. cwts.	1,93 978 8 260	2,10 960 9,020	3,42,670 17,460	1,34,654 11,960	3,52,089 23,020	*2,46,870* *14,064*
Coal, coke and patent fuel.	Rs. tons	1,32,02,319 468,841	1,19,35,578 488,609	45,03,107 194,007	57,55,193 243,653	44,75,509 210,473	*79,74,401* *21,117*
Precious stones and pearls, unset.	Rs.	1,15,80,932	1,18,05,437	1,10,71 399	1,27,57,011	1,22,98,238	*1,19,02 604*
Stone and marble	Rs. tons	4,96,650 3,786	7,71,684 5,774	9,61,334 7,959	7,50,708 6,761	8,00,841 6,172	*7,58,045* *6,090*
Other building materials.	Rs.	1,10,30,909	1,15,71,532	1 22,01,799	1,44 80,040	1,24,68,641	*1,25,33,002*
TOTAL VALUE " "	Rs. £	**43,58,85,849** **31,358,694**	**40, 7,66,509** **30,208,008**	**41,64.61,982** **31,079,252**	**45.72,59.439** **34,123,839**	**45,30,84,566** **33,812,281**	**43,28,91,669** **32,116,415**
		(£1 = Rs. 13·9)	(£1 = Rs. 13·3)	(£1 = Rs. 13·4)	(£1 = Rs. 13·4)	(£1 = Rs. 13·4)	

quinquennium, while those of machinery and millwork show a reduction of nearly 25 per cent.: the decrease is of course exaggerated by the general fall in the value of the rupee.

For comparison with imports of minerals and mineral products into India, it is interesting to give also a table showing the amount and value of exports of minerals and products obtained directly from minerals in India, for the years 1924-28. This is done in Table 5. From this it will be seen that the average annual value of exports during the quinquennium has been Rs. 12,38,96,440 compared with Rs. 43,28,91,669 for the imports during the same period. The most important exports in order of value have been manganese-ore, pig lead, parafin wax, pig iron, mica, mineral oil, tin and tungsten ores, coal, coke and patent fuel, copper.

It is interesting also to collect into one table such reliable labour statistics as are available for the different minerals, in order to show the relative magnitude of the various mineral industries of India during the quinquennium. These figures are shown in Table 6 from which it will be seen that the average number of persons employed daily in all mines for which reliable returns of labour statistics are available during the quinquennium was 334,440 of which 187,907 persons were employed in the coal industry. The most important sources of employment otherwise were the industries for producing manganese-ore, petroleum, salt, gold, mica and iron-ore.

Summary of the Minerals of Group I.

Antimony.

Until the beginning of the quinquennium under report the amount of antimony raised in India, chiefly from the Amherst district of Burma, amounted to a few hundred tons a year. Since 1924, however, antimonial lead has been regularly produced from the Bawdwin mine of the Northern Shan States in Burma to the extent of some 1,020 tons a year.

Chromite.

Chromite being a munition of war, its production during the war period rose from an annual average of 4,671 tons to nearly 23,000 tons; during the following quinquennium it again rose from the latter figure to 35,000 tons, the rise being due principally to the vigorous mining in Baluchistan which doubled its output. During the five years under review there was a 12·3 per cent. decrease in average output from Baluchistan; this was, however, more than balanced by an increased production from Mysore.

TABLE 4.—*Value of Imports of products of a more finished nature manufactured almost entirely from minerals or mineral products for the years 1924 to 1928 (including Government stores).*

—	1924	1925	1926.	1927	1928	*Average.*
	Rs.	Rs.	Rs.	Rs.	Rs	*Rs.*
Railway plant and rolling stock . .	8,39,15,058	7,53 44,065	7,14,94,159	8,44,57,576	(a) 2,21 41,645	*6,74,70,501*
Machinery and millwork . . .	15,53,44,993	15,95,48 216	15,13 37 0[illegible]7	16,57,87 417	21,04 39,807	*16,84,91,502*
Cutlery and hardware . .	5,72,36,344	5,57,79 585	5,95,2[illegible]	5 93,27 685	6,06,84 920	*5,8[illegible],10,812*
Glass and glassware . . .	2,62,81 073	2,57,19 691	2,55,4[illegible]	2 45 48,547	2,49,73,789	*2,56,03 949*
Alizarine and aniline dye . . .	2 84,06,008	1,59 62 802	1 59 06 [illegible]	1,9[illegible] 147	2,45 27,072	*2,09,36,590*
Paints and colours . .	1,05,22,082	99 23,015	1 10,57 6[illegible]	1 [illegible] 59 031	1 11 87,160	*1,09,49,797*
Earthenware and porcelain . .	72,50 167	76 57 577	7[illegible],83 [illegible]76	84,93 293	79,35,476	*78 44,080*
TOTAL VALUE Rs.	35,89,05,725	34,99,34,951	34,37,51.913	37,46,53,696	36,18,89,872	**35,98,2[illegible],281**
. Sterling	26,539,980	26,319,898	25,653,130	27,959,156	26,852,778	26.663,188
	(£1=Rs. 13·[illegible])	(£1=Rs 13 3)	(£1=Rs, 13 4)	(£1=Rs 13·4)	(£1=Rs 13 4)	

(a) Figures are for three months, January to March 1928.

TABLE 5.—*Amount and value of Exports of minerals and products obtained directly from minerals for the years 1924 to 1928.*

—		1924.	1925.	1926	1927.	1928	*Average*
Salt	Tons	1,576	8,984	16,702	13,180	12,212	*10 531*
	Rs.	26,601	1,56,359	3,02,208	2,59,542	2,29,888	*1,94,919*
Saltpetre	Cwts.	167.700	126,973	98,830	123,018	89,570	*121,218*
	Rs.	27,99,213	19,63,301	13,24,540	15,22,666	10,00,034	*17,21,951*
Metals and Ores—							
Borax	Cwts.	5,050	2,563	2,077	1,559	1,075	*2,466*
	Rs	1,54,291	60,168	48,901	42,174	25,876	*66,282*
Chromite	Tons	31,788	48,323	39,951	42,953	45,308	*41,664*
Copper	,,	3,302	7,026	9,638	14 096	11,547	*9 122*
	Rs	16,74,182	34,17,767	46,16,281	63,78,905	48,18,816	*41,81,190*
Ferro manganese	Tons	749	2,258	6 897	3,042	3,108	*3,211*
	Rs	1,35,985	3 67,627	5,59,085	96,443	1,21,045	*2,56,037*
Ferruginous-manganese ore	Tons		9,400	13,050	12,250	11,860	*9,312*
	Rs		56,400	78,300	2,71,500	1,20,600	*1,05,360*
Iron pig	Tons	271,055	401,794	315,162	383 960	428 625	*360 119*
	Rs	1,79,78,296	1,98,66,587	1,42,19,549	1,74,28,304	2,01,50,789	*1,79,28,695*
Lead pig	Tons	46,035	41,137	43 523	58,084	72,661	*52 288*
	Rs.	2,17,63,980	2,00,55,189	2,02,14,077	2,26,19,666	2,11,81,035	*2,11,66,789*
Manganese ore	Tons	747 968	698,878	625,834	866,327	856,515	*759,104*
	Rs.	3,47,52,182	2,94,11,367	1,99,53,297	2,70,58,138	2,51,15,915	*2,72,58,179*
Mica	Cwts	70,095	99,699	89,947	77,488	95,479	*86,542*
	Rs.	94,49 168	1,06 33 123	1,10,00,077	92,63,972	93,54,946	*99,40,257*
Monazite	Tons	190	285	346	503	80	*281*
	Rs.	64,000	56,980	64,350	78,070	15,000	*55 680*
Tin and tungsten ores	Tons	1,832	4,708	3,501	4,821	3,883	*3 748*
	Rs.	35,90,227	59,10,078	66,22,081	94,04,591	61,60,357	*63,97,466*
Zinc	Tons	15,192	20 967	43,056	67,135	76 031	*44,476*
Unenumerated	,,	10,773	10,697	11,594	15,987	18,487	*13,496*
	Rs.	8,63,095	9,06,998	9,09,078	13,03,678	23,37,899	*12,64 150*
TOTAL Rs.		**9,32,51,220**	**9,28,61,885**	**7,99,11,824**	**9,57,27,649**	**9,09,32,200**	**9,05,36,955**
Coal, coke and patent fuel	Tons	206,483	216,090	617,562	576,167	626,343	*448,529*
	Rs.	34,19,098	32,44,091	79,33,246	69,76,112	72,47,597	*57,64,029*
Jadestone	Cwts.	2,724	1,053	1,793	2,309	2,351	*2,046*
	Rs.	7,53,550	1,80,601	3,85,475	3,95,840	4,54,571	*4,34,007*
Mineral oil	Gals.	22,387,938	12,816,274	2,345,360	154,478	140,755	*7,568,961*
	Rs.	2,52 06,099	1,44,06,754	25,56,024	1,45,304	1,48,318	*84 92,300*
Paraffin wax	Cwts	29,407	31,498	40,623	47,700	49,676	*39,780*
	Rs.	1,33,76,818	1,46,19,887	1,99,34,347	2,26,80,704	2,31,77,094	*1,85,77,770*
Precious stones and pearls unset	,,	22,165	56,403	25,775	28,550	19,008	*30,380*
Stone and marble	Tons	2,343	2,643	5,042	4,861	1,773	*3,332*
	Rs.	49,640	51,515	92,466	56,272	55,102	*60,999*
TOTAL	,,	**4,28,27,370**	**3,25,59,251**	**3,00,26,333**	**3,02,82,782**	**3,11,01,690**	**3,33,59,485**
GRAND TOTAL	,,	**13,60,73,590**	**12,54,21,136**	**10,99,38,157**	**12,60,10,431**	**12,20,33,890**	**12,38,96,440**

TABLE 6.—*Average number of persons employed daily in the production of minerals from mines in India for which reliable returns of labour statistics are available.*

—	1924.	1925	1926.	1927.	1928.	*Average.*
Chromite	1,094	1,497	1,257	1,553	1,405	*1,361*
Coal	204,306	189,262	185,749	180,532	179,687	*187,907*
Copper ore	31	..	236	328	652	*249*
Diamonds	540	643	490	629	779	*616*
Gold	20,272	19,736	19,392	19,656	19,055	*19,622*
Iron ore	13,214	12 147	14 038	17,822	13,272	*14,098*
Lead ore	3,557	4 450	5,200	5,611	5,884	*4,840*
Magnesite	2,004	2 460	2 815	2,159	1,794	*2,246*
Manganese ore	30 425	31,118	35,581	39 193	34,710	*34,205*
Mica	15 310	18,563	17 942	20,016	18,367	*18,040*
Monazite, zircon and ilmenite	149	.	170	264	106	*138*
Petroleum	20,809	21,391	23,390	28,426	27,841	*24,371*
Ruby, sapphire and spinel	1,417	899	316	406	507	*715*
Salt	19,982	20,045	19,637	21,180	22,523	*20,653*
Tin and tungsten ores	4,616	6 314	8,315	(b)	7,648	*5,379*
TOTAL	337,726	328,525	334,458	337,775	333,730	*334 440*

(b) Not available.

Coal.

In the case of coal, the output which had risen to over 22½ million tons in 1919, fell in 1920 to about 18 million and; during the three years 1921-23, oscillated between 19,000,000 and 19,660,000 tons. From 1924 to 1926 it maintained a steady level at about 21 million tons, rising to over 22 million in 1927 and again exceeding 22½ million tons in 1928. During the war, there was a marked rise in raising costs, and the pit's mouth value rose from Rs. 3-9-0 to a record figure of Rs. 4-6-0 in 1918. This figure was altogether eclipsed by that for 1922, which reached Rs. 7-10-0 per ton. In 1923 it fell to Rs. 7-7-0, which was still more than double the pre-war rate. From then onwards there was a rapid and continuous fall to Rs. 3-12-0 in 1928. The decrease in value of the output during the past quinquennium is, therefore, much greater relatively than the general increase in quantity.

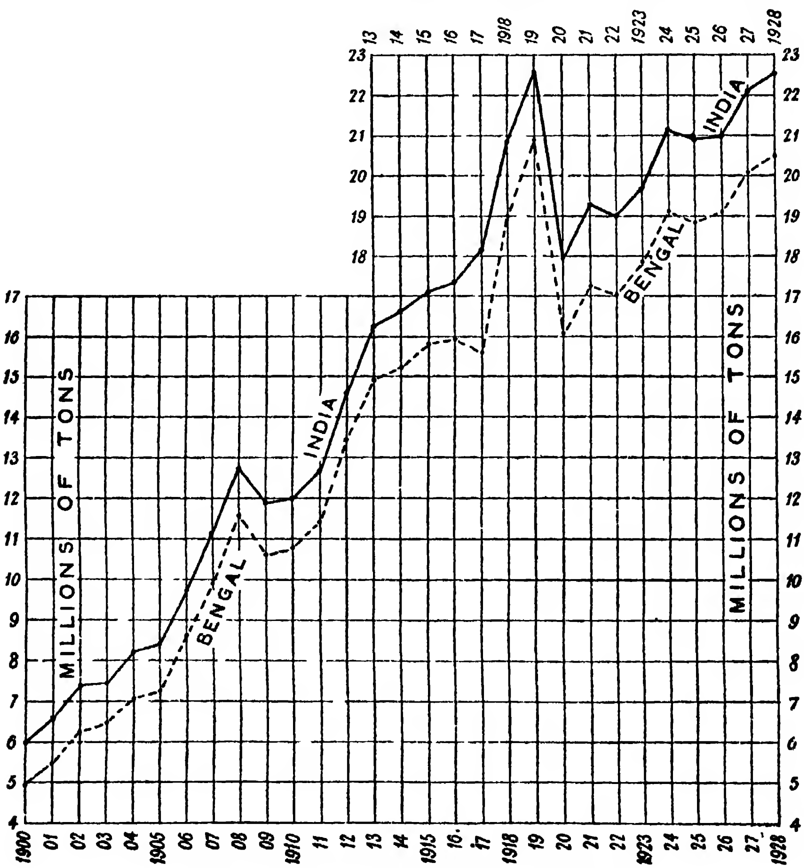

FIG. 1.—*Production of Coal from 1900-1928.*

Throughout the period, India still held her position as the largest coal-producer of any of the British dependencies. She was again completely outdistanced by Japan, whose output in 1927 was about 32½ million tons against India's 22 millions. The Gondwana fields produced about 98 per cent. of the Indian output, and the Raniganj and Jharia fields respectively 28·6 and 49·4 per cent. The Bokaro field contributed on an average 7·6 per cent. of India's total output; before many years this is likely to prove one of the great Indian fields.

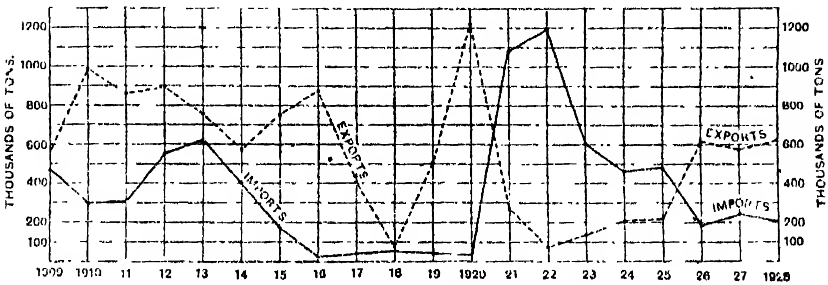

FIG. 2.—*Exports and imports of Coal for the past 20 years.*

As might be expected, imports and exports of coal were abnormally low throughout the war period and fell to about 54,000 tons and 74,000 tons respectively in 1918. Imports fell still lower in 1919 and 1920, in the latter year not amounting to 40,000 tons; in 1921 there was a jump to over 1 million tons which increased in the following year but fell to 625,000 tons in 1923. There was a further decrease in 1924 to 464,000 tons, and a slight increase in 1925 to 483,000; further subsequent decreases brought the average figure for the quinquennium down to 319,000 tons. Exports during the quinquennium shewed a similarly extreme variation, the highest figure being that for 1928, 626,000 tons, and the lowest that for 1924, 206,000 tons; the average exports amounted to 448,500 tons a year. Both Japan and South Africa must be regarded as formidable rivals in Indian Ocean ports.

The employment of by-product ovens in coke-making has extended considerably. The amount of coal or coke used for domestic purposes in such a densely populated country as India is, however, astonishingly small. A greater demand would encourage the exploitation of large untouched reserves of second quality coal and would defeat the reprehensible practice of burning a valuable manure

such as cowdung for cooking purposes. The by-products recovered are tar and ammonia, sulphate of the alkali being manufactured with acid made locally from imported sulphur.

One of the outstanding improvements adopted during the past ten years in the coalfields is the greatly extended use of electricity for pumping, ventilation, haulage, coal-cutting, etc., especially for the first mentioned purpose.

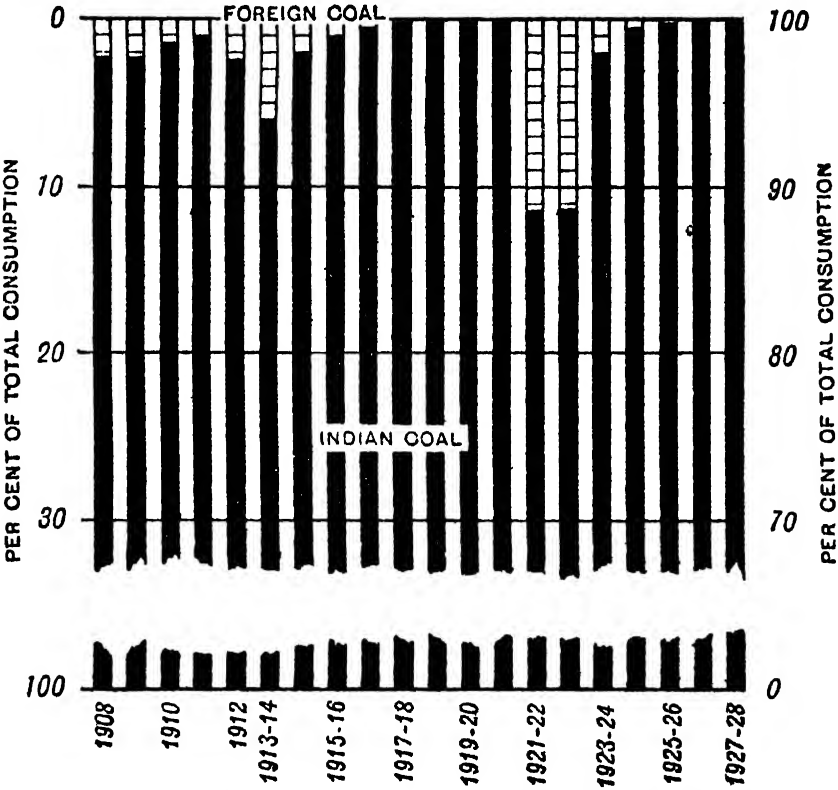

FIG. 3.—*The relative consumption of Foreign and Indian coal on Indian Railways*

Copper began to figure regularly in our mineral returns during the quinquennium 1914-18; unfortunately, the Cape Copper Company's operations at the Rakha Mines were delayed by the difficulty of importing materials for furnaces, etc., during the war, and the production, which had risen to 20,000 tons in 1917, fell to only 3,600 tons in 1918.

Copper.

Smelting operations were begun in 1918 and a small amount of blister copper produced, but the average annual output for that period was below 8,054 tons. During the period 1919-23 the average annual output of copper ore by the Cape Copper Company rose to 26,159 tons. This company went into liquidation in 1923. In 1924 a new company, the Indian Copper Corporation, continued the successful operations of the Cordoba Copper Company, with the result that the annual output of ore during 1924-28 averaged 11,776 tons. The Bawdwin mine of Upper Burma now yields a regular supply of copper matte containing about 41 per cent. of copper, the average production of this matte per year during the quinquennium under review having been a little over 9,000 tons.

Diamonds.

The average annual output of diamonds rose from 162 carats in the preceding quinquennium to 224 carats in the period under report.

Gold.

Gold-mining, as might be expected, was one of the few mineral industries that suffered from the war. The Indian output fell steadily from 1915 onwards, and the output decreased by over 80,000 oz. in 1918. The average annual production for the war period was a little under 587,000 ounces. The fall in the output of gold continued and the average annual output during 1919-23 amounted to 459,875 oz. or 126,704 oz. less than that of the preceding quinquennium. The deficit in the case of the quinquennium under consideration was less, the annual output during 1924-28 averaging 386,944 oz.

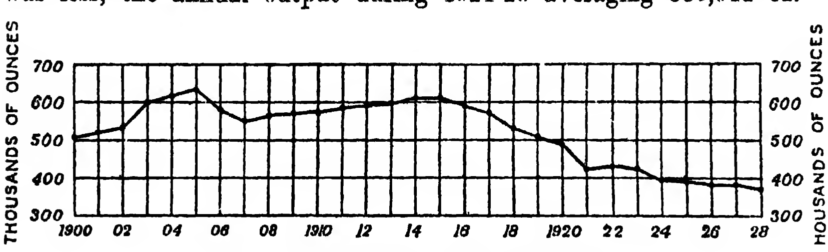

FIG. 4.—*Production of Gold since 1900.*

Graphite.

Owing to the difficulty of obtaining graphite from extra-Indian sources, there had been a slight revival of indigenous mining during the war period, but it did not persist. The output of graphite amounted to 127 tons in 1919,

100 tons in 1920 and 25 tons in 1921. But for a small output of 20 tons from Mysore the industry would have died out in 1922. There was no production in 1923 nor during the five years which followed. No attempt has been made to open the Travancore mines.

Iron.

In the period under review, the advance in the Indian iron and steel trade has been less than was expected. The Bengal Iron Company's outputs of metal during 1923 had increased to 119,379 tons of pig iron and 33,627 tons of castings. The first figure rose to 147,733 tons in 1924, but the annual average for the five years amounted to 96,244 tons only; the average output of castings by this company was 53,698 tons per year. The Tata Iron and Steel Company, who had practically doubled their output during the previous five years, maintained a steady output averaging some 569,500 tons of pig iron and some 319,000 tons of steel during the quinquennium under consideration. The Indian Iron and Steel Company, who commenced smelting operations at the end of 1922, produced an annual average of 286,000 tons of pig iron during the period now under consideration, while the corresponding figure for the Mysore Iron Works amounted to 17,500 tons. The United Steel Corporation of Asia, Limited, have not yet erected any plant but have been producing iron ore since 1927. The Steel Industry (Protection) Act -No. XIV of 1924- authorised, to companies employing Indians, bounties upon rails and fish-plates wholly manufactured in British India from material wholly or mainly produced from Indian iron ore and complying with specifications approved by the Railway Board, and upon iron or steel railway wagons a substantial portion of the component parts of which had been manufactured in British India. This Act was repealed by Act No. III of 1927 and the payment of bounties consequently ceased on the 31st March, 1927; the Industry is, however, protected to a certain extent by varying tariffs on different classes of imported steel.

Jadeite.

There has been no real advance in the jadeite industry, which is a primitive one carried on in unadministered territory in the neighbourhood of the Hukong.

Lead and Silver.

There has been further marked progress in the operations of the Burma Corporation, Limited, at Bawdwin and Namtu, the property being now proved as one of the great lead-silver-zinc mines of the world. The output of lead extracted from the ore rose steadily from 19,000 tons in 1919 to over 77,000 tons in 1928; the annual production during 1924-28 averaged 58,523 tons *plus* 1,020 tons of antimonial lead. The output of silver also increased, averaging nearly 5¾ million oz. per year as against 3½ million oz. for the previous five-year period. Copper and nickel are also being produced from this mine.

Magnesite.

The average annual output of magnesite, which had increased by 77 per cent. during the post-War quinquennium, further increased to some 26,000 tons during the five years 1924-28. The production was derived mainly from the deposits in Salem, Madras, with a small contribution from Mysore.

Manganese.

With respect to manganese, India in 1907 overtook Russia, which was at that time the greatest producer of that mineral, and assumed the first place amongst the world's suppliers of manganese-ore (*see* Plate 6). This lead was lost during the years 1912-15, but the War reinstated India, so far as the high-grade ore was concerned, in her former supremacy, in spite of increased competition from Brazil due to the same cause. Events since the War have not yet led to any change in the relative position of these three leading producers, but Brazil has since 1924 been ousted by the Gold Coast which now occupies third position among the world's producers. The record for the present period in India has been that of a relatively stable industry which has found its level in the world and has taken advantage of expanding markets. Competition and falling prices have, however, begun to affect the prosperity which the manganese industry has enjoyed up to the year 1927. The period of discovery of new and valuable deposits of manganese-ore seems to have passed. From 1924 the annual production rose from some 803,006 to 1,129,353 tons in 1927; the latter is the highest yet recorded annual production. In 1928 the production dropped to about 978,500 tons.

Exports of manganese-ore from Russia from the middle of 1914 up to the end of 1921 were negligible, but business was resumed again in 1922 and steadily increased in 1923. The exports for 1922 amounted to some figure between 80,000 and 170,000 tons;

in 1923 they increased to about 350,000 tons. From 1924 to 1927 this figure rose from nearly 485,900 tons to nearly 772,300 tons; the figure for 1928 is not yet available, but will probably show a decrease. As before the War, the bulk of the ore came from the Chiaturi region of Georgia.

The price of first-grade ore, c.i.f. United Kingdom ports, fell from 22·9*d.* per unit in 1924 to between 16½*d.* and 18½*d.* (for best Indian and washed Georgian ore) in January, 1928. This fall in price had been anticipated five or six years ago, when it became known that the Harriman group of American financiers were negotiating with the Soviet Government for the development on modern lines of the Caucasus manganese ore. It might seem at first as if the termination of the Harriman interests in Russia, which became definite in 1928, would benefit the Indian producer. There is little doubt, however, that the Soviet, owing to their methods of purchasing labour, hold the key to the manganese situation and have it in their power to under-sell outsiders. The Soviet position is none-the less unsound, and the chances are that the recently discovered large deposits at Postmasburg in the northern part of Cape Province of South Africa will prove a more formidable rival to Indian manganese than the lower-grade Russian material. Brazil is hampered by inadequate transport facilities. The Gold Coast has, in fact, outstripped Brazil, and is another competitor which India has to consider.

During the five years 1923 to 1927 the proportions contributed by India, Russia with Georgia, the Gold Coast, and Brazil, in the order named, were 35·2 per cent., 24·5 per cent., 12·2 per cent. and 9·8 per cent., respectively, of the world's output, which averaged 2,625,600 statute tons annually. The United States produced as much as 305,869 tons in 1918, a figure which, promoted by war conditions, will probably never again be approached unless the stimulating conditions are repeated. The United States average output for 1924-28 amounted to 60,402 tons per annum.

The average annual value of the ore produced in India during the years 1909-13 was £822,876. This increased to £1,052,403 for the period 1914-18, and again to £1,995,341 during 1919-23, the maximum value being £3,525,842 in 1920. During the period 1924-28 the average annual value of the Indian production amounted to £2,018,835, f.o.b. Indian ports. Taking the average values for the period, manganese-ore has taken a third position amongst the minerals produced in India, being exceeded by coal and petroleum only, and having superseded gold.

From figure 5 it is seen that all provinces, except Bihar and Mysore, shared in the continual rise in output during the first four years of the quinquennium. The rise in the case of Bihar took place during the last two years.

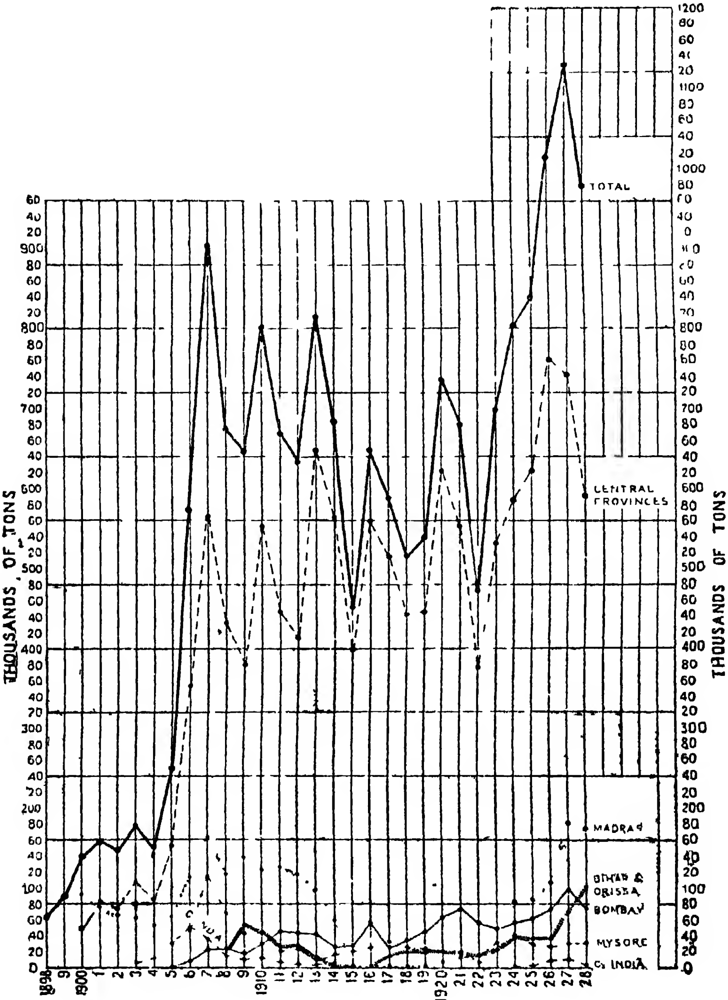

Fig. 5.—*Production of Manganese ore since 1898.*

Mica.

India is still the greatest mica-producing country in the world; the fields of Hazaribagh and Nellore produce something like 65 per cent. of the world's supply of sheet mica, the United States and Canada being next in im-

portance. The production of fine splittings by hand is an art which is performed to perfection in India. In fact, when the demand for mica splittings is brisk, a certain amount of mica is actually imported into India for conversion into fine splittings and subsequent export. India also holds a monopoly in the production of shellac, and has it in her power to hold a predominant position in the manufacture of micanite, an artificial commodity made out of the smallest and thinnest films of mica cemented together with shellac dissolved in spirit. Figure 6 shows the fluctuations in the total weight and total value of the mica exported during the past twenty years.

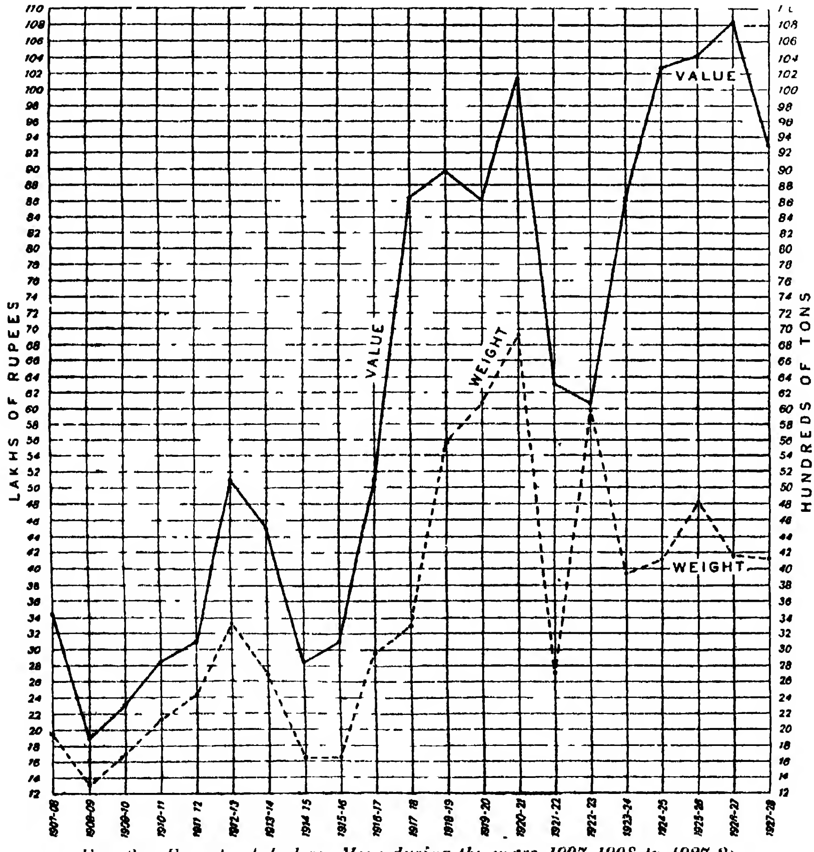

FIG. 6. *Exports of Indian Mica during the years 1907-1908 to 1927-28*

There was a sharp decline in the production of monazite in Travancore, when compared with production during the previous five-year period. The industry has been kept alive by the sister-industry of Ilmenite.

Monazite.

Nickel.

A regular production of nickel from the Bawdwin mine of Upper Burma was initiated in 1927 and is likely to become a regular feature of the mineral output from this area. The amount of speiss, containing 24·8 per cent. of nickel, obtained in 1928 was 2,933 tons, estimated to be worth £39,922. The speiss contains from 3 to 4 per cent. of cobalt.

Petroleum.

The average annual value of petroleum produced has decreased from £7,036,298 for the period of the preceding review to £6,268,229 for the present period. The fall in the exchange value of Indian currency partially accounts for this. The exports of paraffin wax rose from 588,140 cwts. in 1924 to 993,520 cwts. in 1928, but the peak production figure for 1928 is not likely to be exceeded to any appreciable extent in the future.

Fig. 7.—*Production of Petroleum since 1900.*

Ruby, Sapphire and Spinel.

Next to petroleum rubies used to form the chief source of revenue amongst the mineral products of Burma. In recent years, however, the industry has been outstripped by those of silver, lead, tin and tungsten. The Burma Ruby Mines, Limited, paid formerly an annual rent of two lakhs of rupees (£13,333) and a royalty of 30 per cent. of their annual net profits. These terms were subsequently modified owing to continued depression in the industry. The average value of the annual output of rubies, sapphires and spinels for the period under review was £26,228, as compared with £60,660 during the preceding period.

Salt.

The amount of salt produced annually during the period 1924-28 has amounted on an average to 1,536,932 tons, which shows a decrease of 161,066 tons over the figure for the previous quinquennium. The annual imports increased from 517,894 tons in 1919-23 to 580,943 tons in 1924-28. Statistics shew that the consumption per head has fallen to the extent of about 6 per cent. bringing it to the level of pre-War days.

Saltpetre.

Owing to the withdrawal of restrictions on the manufacture of saline substances in India, production figures for saltpetre subsequent to 1924 are no longer available. The average annual exports exceeded 6,000 tons, the greater part of which went to Ceylon.

Tin.

In contrast with the stagnation of the sister industry of wolfram, tin mining has again progressed steadily during the five-year period 1924-28. The high price of tin has played an important part in the increased output, which rose from an average annual figure of 138 tons valued at Rs. 4,15,295 during the five years 1919-23 to 2,802 tons valued at Rs. 47,43,602 during the quinquennium under review. Much of the work had originally been carried out on primitive native principles, but dredging machinery is now a permanent feature, and many of the alluvial flats in Tavoy and Mergui have been and are being systematically tested. Concessions have been granted for searching for tin-ore beneath the sea along the Tenasserim coast and will, it is hoped, meet with the success which has attended similar efforts in Java and other Eastern countries.

The large quantities of high-speed tool-steel required throughout the world in consequence of the war, led to a greatly increased demand for tungsten and its raw materials, wolfram and scheelite. Vigorous measures were taken to increase production in Burma; by the year 1917 the output had been more than doubled and amounted to 4,542 tons. The value rose in even greater proportion from £175,150 in 1914 to £726,681 in 1918. These figures, however, were artificial; the price per unit was fixed by the British Government at a figure considerably above the previous market rate and all wolfram was taken over at that price. This, although highly profitable to the producer, did not represent the true market value of the material, the price offered in the American market being nearly double the control rate. After the War the wolfram market suffered an expected collapse, and mining operations in Burma dwindled to an output of under 900 tons in 1921. There has been no appreciable recovery since, the average annual production during the quinquennium amounting to 955 tons. China still dominates this market and exported some 7,000 tons of ore in 1926 and approximately 5 000 tons in 1927.

Tungsten.

III.—DETAILED ACCOUNT OF THE MINERALS OF GROUP I.

Antimony.

[E. H. PASCOE.]

Shigri.

A mining lease to work the well-known antimony-ores (stibnite with oxides) near the Shigri glacier in Lahaul, Punjab, was granted in 1904 to Colonel R. H. F. Rennick. The stibnite lodes are associated with gneissose granite and are situated at an elevation of 13,500 feet; to reach the locality it is necessary to cross the Hamta pass (14,500 feet). Work is possible for two or three months only in the year and labour and supplies have to be brought from the nearest village, 3½ marches away. In spite of these difficulties, however, Colonel Rennick succeeded in 1905 in shipping over 400 *maunds* (15 tons) of stibnite to England, making use of migratory flocks of sheep as transport. Since then further quantities were quarried and the deposits are thought to be extensive enough to yield 200 to 400 *maunds* of stibnite a year, but no further shipments were made on account of the low price of star regulus. The stibnite has yielded 6 dwts. of gold per ton. Galena and blende are also found in the same locality, the former being argentiferous. No production from this area has been reported since the quinquennium 1904-08.

Southern Shan States.

The existence of an antimony deposit of considerable size in the Mong Hsu state, one of the Southern Shan States, was considered to be indicated by the return, amongst the mineral statistics for Burma for 1908, of an output, under a mining lease held by Mr. W. R. Hillier of Lashio, of 1,000 tons of antimony-ore, of which 11 tons were sent to London for assay and valuation. The output from the Southern Shan States in the following year was recorded as 2½ tons, since when there have been no returns. Further details regarding these deposits have been published in the Records of this department by Mr. H. C. Jones, who concludes that none of them appears to be large or of much economic value.[1]

[1] *Rec. Geol. Surv. Ind.*, LIII, pp. 44-50 (1921).

Amherst district, Northern Shan States and other localities.

In 1905, stibnite with cervantite was found in the Northern Shan States.[1] The lead slags at Shekran in Jhalawan, Baluchistan, have been found to be antimonial.[2] The tetrahedrite found in the Sleemanabad copper lodes[3] is also highly antimonial. A few pounds of antimony-ore were recorded from the Jhelum district, Punjab, for the years 1914 to 1918, but no output has been reported since. Stibnite has for many years been known to exist in the Amherst district of Burma. In response to a considerable demand for antimony during the year 1916, the supply from this district, derived from two or three localities, was increased to 1,000 tons, but fell to 105 tons in 1917 and to *nil* in 1918. Dr. A. M. Heron recently investigated these occurrences and concluded that, at the price of antimony obtaining in 1921, some of them could be profitably exploited; a description of his work has been published in the Records of this department.[4] During the quinquennial period under consideration 10 tons of antimony-ore, valued at Rs. 345, were produced in the Amherst district in 1925, 108 tons valued at Rs. 2,688 in 1926, 500 tons valued at Rs. 10,500 in 1927 and 370 tons valued at Rs. 10,300 in 1928. Mysore responded to the same stimulus but the production fell to 0·1 ton in 1918, and has since ceased. Since 1924 antimonial lead has been obtained as a by-product in the refining of lead at the Namtu smelter of the Burma Corporation. The yield in 1924 was 1,200 tons valued at Rs. 3,06,172 (£22,027), in 1925 1,100 tons valued at Rs. 2,83,909 (£21,347), in 1926 1,057 tons valued at Rs. 3,20,500 (£23,918), in 1927 503 tons valued at Rs. 1,33,065 (£9,930), and in 1928 1,241 tons valued at Rs. 3,17,011 (£23,658). This product contains approximately 77 per cent. of lead, 21 per cent. of antimony and from 6 to 8 oz. of silver to the ton, and is exported to the United States of America for further treatment.

Uses.

Antimony is mostly used for the hardening of alloys, to which it gives the useful property of a slight expansion on solidification. For this purpose it is an ingredient of type-metal, and is responsible for the sharp definition of the type. Nearly three-fourths of the antimony produced

[1] L. L. Fermor; *Rec. Geol. Surv. Ind.*, XXXIII, p. 234 (1906).
[2] G. H. Tipper; *ibid*, XXXV, p. 51 (1907).
[3] L. L. Fermor; *ibid*, XXXIII, p. 62 (1906).
[4] *Rec. Geol. Surv. Ind.*, LIII, p. 34 (1921).

in the world is used for the following four purposes: the manufacture of (1) battery plates (in the form of antimonial lead); (2) 'babbitt' metal; (3) solder and other soft metal alloys, and (4) hard-lead for pipes, taps, etc. It is also used in the preparation and manufacture of pigments (especially the yellow sulphide), matches, fireworks, enamel frits, cable sheathing, glass (colouring and 'fining' agent), bearing or anti-frictional metal, brass (including bronze), shrapnel and other bullets, foil, lighting fixtures, primers for explosives, furniture-polish and medicines. It is used in the rubber industry, and as a mordant in dyeing and calico-printing.

Chromite.

[E. H. PASCOE.]

Occurrences of chromite in India are usually associated with serpentine and other rocks of the peridotite family, and are known in Baluchistan, in Mysore, in the Singhbhum district of Bihar and Orissa, near Salem in Madras and in the Andaman Islands. Serpentine and peridotite are found in large quantities in the Minbu district of Burma, in Manipur[1] and further north in the direction of Sarameti peak in the heart of the Arakan Yoma[2]; the chances of discovering chromite in the last mentioned locality are good, though none has so far actually been reported. The deposits at Karuppur in the 'Chalk Hills' near Salem have been known for a long time, and attempts were made many years ago to work them but were given up. The mineral is found in very thin veinlets lying either amongst the magnesite or between the magnesite and the wall of the magnesite vein. Veins of chromite of some size must, however, occur somewhere in these hills, for in many of the streams pieces of the mineral ranging up to a foot across have been picked up.[3] The ore, of which some 100 tons were removed during the earlier half of the last century, yielded on analysis 49 per cent. of Cr_2O_3. According to Holland the chromite is here associated with intrusions of dunite. A small vein of chromite, 4 inches thick, crops out in the Kanjamalai hill near by.

Blocks of chromite were found near the village of Chakargaon near Port Blair in the Andaman Islands, but the mineral was not

R. D. Oldham; *Mem. Geol. Surv. Ind.*, XIX, pp. 224-225 (1883).
E. H. Pascoe; *Rec. Geol. Surv. Ind.*, XLII, p. 258 (1912).
C. S. Middlemiss; *Ibid*, XXIX, p. 34 (1896).

found *in situ* and appeared to be confined to one spot; no attempt has been made to work it.[1] No trace of chromite has been found in the serpentine series of the Middle Andaman during a recent survey.

Baluchistan.

Chrome iron ore was noted in Baluchistan by Vredenburg in 1901, who reported its occurrence in segregated masses of serpentine along the hills bordering the Zhob valley and in the upper valley of the Pishin river. In one spot, some two miles east of Khanozai, a mass of almost pure ore measuring about 400 feet in length and 5 feet in breadth, was found. Work was commenced in 1903, the production for the first year being returned as 284 tons. The industry received a gigantic impetus during the Great War and the output rose in 1918 to nearly 23,000 tons. In 1919 it was affected by the general lump which succeeded and fell to about 13,200 tons. In 1920 it recovered itself, and the average annual output for the five years 1919-23 amounted to 20,358 tons. The total output for the two producing districts, Quetta-Pishin and Zhob, is shewn in Table 7. The average annual output of Baluchistan for the period under review was 17,855 tons, being a decrease of 12·3 per cent. over the preceding quinquennium, The chromite, which is exported from Karachi, is of high grade.

Mysore.

In Mysore State chromite occurs in the districts of Hassan, Mysore, Kadur and Shimoga. It has been worked in the first three districts only, the production for 1907, the first year of work, being 11,029 tons. The output, which had sunk to *nil* in 1910, 1911 and 1912, rose like that of Baluchistan during the War and owing to the extraordinary vigour of Messrs. Oakley, Bowden and Company, who held a prospecting license, reached the high figure of 33,740 tons, much of it high grade ore, in 1918. In 1919. 22,372 tons were raised, but a slump ensued in 1920, 1921 and 1922, during which the average output fell to 4,598 tons. In 1923 there was a smart recovery to 29,009 tons, and the past quinquennium has witnessed an average annual production of 23,833 tons, most of which was derived from the Hassan district; the only contribution, amounting to 1,900 tons, from the Kadur district was made in 1925. Chromite seems to have been first found in Mysore State by Mr. H. K. Slater, who discovered a rock shewing grains of chromite

[1] *Rec. Geol. Surv. Ind.*, XVI, p. 204 (1883) and XVIII, p. 83 (1885).

TABLE 7.—*Production of Chromite during the years 1924-1928.*

PROVINCE.	1924		1925		1926		1927		1928		*Average.*	
	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*
	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*
Baluchistan—												
Quetta-Pishin.	81	*403*	10	*150*	..	..	..	--	..	--	18	*110*
Zhob . .	26,629	*3,81,810*	18,188	*2,65,121*	14,832	*2,17,715*	14,534	*2,18,014*	15,002	*2,25,030*	17,837	*2,61,538*
Bihar and Orissa—												
Singhbhum .	1,140	*19,241*	3,038	*69,274*	1,623	*37,028*	2,552	*49,431*	2,165	*48,949*	2,104	*44,785*
Mysore State—												
Hassan . .	13,791	*1,09,528*	8,662	*82,896*	10,827	*97,116*	34,030	*4,88,076*	23,639	*3,86,008*	18,190	*2,32,725*
Kadur . .	..	..	1,900	*15,200*	..	..	..	..	..	..	380	*3,040*
Mysore .	3,821	*76,420*	5,654	*1,01,639*	6,100	*61,000*	6,091	*1,25,436*	4,649	*1,05,681*	5,263	*94,035*
TOTAL .	45,462	*5,87,402*	37,452	*5,34,280*	33,382	*4,12,859*	57,207	*8,80,957*	45,455	*7,65,668*	43,792	*6,36,233*
Total value in sterling.		*£42,259* (£1 = Rs. 13-9)		*£40,171* (£1 = Rs. 13-3)		*£30,810* (£1 = Rs. 13-4)		*£65,743* (£1 = Rs. 13-4)		*£57,139* (£1 = Rs. 13-4)		*£47,224*

in a talcose matrix near Harenhalli in the Shimoga district.[1] Even the richest specimens did not indicate more than 35 to 40 per cent. of Cr_2O_3.

Bihar and Orissa.

A geological survey of the chromite area to the west of Chaibassa in Singhbhum, discovered by Mr. R. Saubolle in 1907, has shewn that the ore occurs as bed-like veins and as scattered granules in serpentinized saxonites and dunites forming laccolitic intrusions several hundred feet thick in Dharwar slates and slaty shales. As in Baluchistan the chromite is of primary (magmatic) origin and contemporaneous with the peridotites. The subsequent serpentinization of the peridotites has been accompanied by widespread silicification with the production of marginal zones of chert. The ore-bearing horizon is unusually persistent over a considerable distance, but the total amount of ore does not appear to be large. As exported the ore carries 50 per cent. of Cr_2O_3 and upwards, but the possibility of concentrating ores of lower grade is worth consideration. The output from Singhbhum has been small but steady and averaged 2,104 tons during the five years under consideration, as compared with 1,611 tons a year during the previous five years.

Coal.

[CYRIL S. FOX.]

Introduction.

More than 150 years have elapsed since the first efforts were made in 1774, in the time of Warren Hastings, to utilise Indian coal for public purposes. It is only since about 1815 that mining operations have been more or less sustained. The discovery and development of various coal-fields, irregular at first owing to the difficulties of transport and the uncertainty of demand, has continued since 1829. Between the years 1882 and 1919 Indian coal production increased steadily—being somewhat accelerated during the War period 1914-1918. The highest output of coal recorded from Indian mines is that of 1919, when the production totalled 22,628,037 tons. With the cessation of the War, at a time when the various collieries were in a condition to meet increased demands, there were all the potentialities of a slump. Indian coal vendors were to some extent

[1] *Rec. Mysore Geol. Dept.* II, p. 129. *Rep. Chief Inspect. Mines, Mysore,* 1906-07, p. 36.

fortunate in that the slump in prices did not immediately accompany the diminished demand. Owing to the shortage of wagons, to underground fires, to floods, to sickness and labour trouble, the collieries were at first unable to supply the markets and the prices of coal soared. In the course of two or three years the congestion had disappeared and the long expected fall in prices began in 1923 and has continued throughout the quinquennial period, 1924 to 1928, under review. Although the output of coal has improved steadily during the past five years, the total value of the coal has decreased year by year owing to the severe fall in the price of coal. The year 1928 is the worst of all in this respect, as seen in the accompanying Tables 8 and 10.

I.—Statistical information on Indian coal.

It has been customary to discuss first the statistical data when reviewing the progress of the Indian coal industry at each quinquennial period. The past decade has been of such a character that the details of the last five years do not give a complete review. In the circumstances, I have found it best to give statistical information for the whole period since the Armistice. These particulars, given in a series of Tables, relate to the production, consumption, exports and imports of coal. Whenever possible, a comparison has been made of the production of competitive countries, *e.g.*, South Africa, Australia and Japan; and of the imports of Ceylon and the Straits Settlements. The Tables have been arranged in the following order :—

(8) Production and value of Indian coal during the years 1919 to 1928.

(9) Output of Indian coal by Provinces for the years 1919 to 1923 and 1924 to 1928.

(10) Average pit's mouth value (per ton) of Indian coal extracted from the mines in each Province during the years 1919 to 1923 and 1924 to 1928.

(11) Declared export value per ton compared with value at the pit's mouth for the years 1919 to 1928.

(12) Production of coal (including lignite) in the four largest British Dependencies during the period 1917 to 1927.

(13) Comparison of Indian and Japanese coal statistics—Production, imports, and exports, since 1885.

(14) Relation of Indian production of coal to total consumption of coal in India during the period 1919 to 1928.

(15) Estimated consumption of coal in India in the official years 1922-23 and 1927-28.

(16) Coal consumed on Indian railways during the years 1918-19 to 1927-28.

(17) Coal carried for the public, etc., by Indian railways and compared with the earnings from coal traffic by these railways during the years 1918-19 to 1927-28.

(18) Indian imports and exports of coal annually since 1914.

(19) Origin of foreign coal imported into British India for public use during the years 1919 to 1928.

(20) Exports of Indian coal to foreign ports during the years 1919 to 1928.

(21) Exports of Indian coal from Calcutta to Indian ports during the years 1919 to 1928.

(22) Ceylon. Imports of coal into Ceylon during the years 1919 to 1928.

(23) Straits Settlements. Imports of coal into the Straits Settlements during the years 1919 to 1927.

These 16 Tables (8 to 23) are given below :—

TABLE 8.—*Production and value of Coal during the years 1919 to 1928.*

Year.	Quantity.	Total value at the mines		*Average value per ton at the mines.*	
	Tons.	Rs.	£	Rs. A.	*s. d.*
1919 . . .	22,628,037	10,11,92,564	8,799,353(*a*)	4 8	*7 10 (a)*
1920 . . .	17,962,214	9,29,78,532	9,297,853(*b*)	5 3	*10 4½(b)*
1921 . . .	19,302,947	13,01,00,652	8,673,377(*c*)	6 12	*9 0 (c)*
1922 . . .	19,010,986	14,63,30,142	9,755,343(*c*)	7 11	*10 3 (c)*
1923 . . .	19,656,883	14,60,59,747	9,737,316(*c*)	7 7	*9 11 (c)*
1924 . . .	21,174,284	14,96,53,419	10,766,433(*d*)	7 1	*10 2 (d)*
1925 . . .	20,904,377	12,64,00,908	9,503,828(*e*)	6 1	*9 1 (e)*
1926 . . .	20,999,167	10,14,99,634	7,574,599(*f*)	4 13	*7 2 (f)*
1927 . . .	22,082,336	9,48,70,013	7,079,852(*f*)	4 5	*6 5 (f)*
1928 . . .	22,542,872	8,84,95,027	6,604,106(*f*)	3 15	*5 11 (f)*

(*a*) Rupee = 1*s.* 8⅞*d.* (*b*) Rupee = 2*s.* (*c*) Rupee = 1*s.* 4*d.*
(*d*) Rupee = 1*s.* 5¼*d.* (*e*) Rupee = 1*s.* 6*d.* (*f*) Rupee = 1*s.* 6*d.*

TABLE 9.—*Output of Indian Coal by Provinces for the years 1919 to 1923 and 1924 to 1928.*

Province.	1919	1920	1921	1922	1923	Total. 1919 to 1923.	1924	1925	1926	1927	1928	Total. 1924 to 1928.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Assam . .	291,734	325,535	312,465	348,103	326,149	**1,603,986**	334,842	318,842	301,061	323,342	298,089	**1,576,176**
Baluchistan .	34,328	33,941	54,627	60,135	42,562	**225,593**	40,557	34,797	15,586	14 444	17,931	**123,315**
Bengal . .	5,777,632	4,207,452	4,259,642	4,328,986	4,621,57-	**23,195,290**	5,031,655	4,913,852	5,137,688	5,554,990	5,639,993	**28,278,178**
Bihar and Orissa	15,119 812	11,975,656	12,990,481	12,711,328	13,212,250	**66,009,527**	14,105,529	13,938,509	13,955,775	14,517,866	14,827,453	**71,345,132**
Burma . .	1,500	..	300	172	1,271	**3,243**	255	25	..	..	..	**280**
Central India .	182,141	158,051	192,034	161,231	175,950	**869,407**	235,298	219,106	216,708	217,661	218,750	**1,107,523**
Central Provinces	497,021	491,205	712,914	675,916	548,074	**2,925,130**	679,081	708,554	635,252	666,758	732,353	**3,421,998**
Hyderabad .	662,196	694,080	688,721	642,880	658,429	**3,346,306**	644,775	667,877	637,779	707,213	734,765	**3,392,409**
North-West Frontier Province.	20	..	..	..	..	**20**	..	..	..	..	..	..
Punjab . .	46,893	58,078	67,242	67,180	63,501	**302,894**	80,422	74,662	65,043	62,704	46,152	**331,983**
Rajputana (Bikanir).	14,760	18,216	24,521	15,055	7,119	**79,671**	21,870	28,153	31,275	17,358	27,386	**126,042**
Total .	**22,628,037**	**17,962,214**	**19,302,947**	**19,010,986**	**19,656,883**	**98,561,067**	**21,174,284**	**20,904,377**	**20,999,167**	**22,082,336**	**22,542,872**	**107,703,036**

TABLE 10.—*Average pit's mouth value (per ton) of Coal extracted from the mines in each Province during the years 1919 to 1923 and 1924 to 1928.*

Province.	1919	1920	1921	1922	1923	Average 1919 to 1923	1924	1925	1926	1927	1928	Average 1924 to 1928.
	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.
Assam . .	7 10 6	7 7 9	7 13 4	8 5 4	8 11 1	8 0 0	8 12 11	8 10 1	7 13 9	12 11 7	12 12 2	10 2 6
Baluchistan .	15 12 2	16 9 9	14 1 8	13 7 5	14 14 4	14 15 6	15 14 2	13 0 9	9 7 5	8 6 4	9 2 4	11 3 0
Bengal . .	5 0 1	6 5 5	7 11 8	9 10 1	9 1 9	7 9 0	8 0 11	6 12 6	5 3 7	4 7 0	3 15 8	5 11 2
Bihar & Orissa .	4 1 2	4 9 2	6 6 10	6 15 5	6 13 7	5 12 5	6 11 9	5 11 3	4 9 6	3 15 11	3 10 6	4 15 0
Central India .	3 9 7	4 4 10	5 11 6	5 13 6	5 13 0	5 0 11	5 12 11	4 9 3	4 9 1	4 6 3	3 14 0	4 10 8
Central Provinces	5 7 0	5 13 3	7 0 0	7 10 7	6 10 7	6 8 3	6 1 5	6 3 2	5 4 2	4 6 7	4 3 4	5 3 9
Punjab .	11 12 8	12 3 10	14 13 8	14 13 10	9 15 10	12 12 0	8 11 5	8 3 5	7 4 9	7 2 6	6 11 8	7 0 11
Rajputana .	6 9 0	7 7 1	8 13 4	7 2 2	6 13 9	7 5 10	7 1 4	6 15 2	6 3 9	6 14 4	6 12 5	6 12 7

In the following Table 11, the average value of the coal at the pit's mouth, obtained from both Bengal and Bihar & Orissa figures, is compared with the average declared export value per ton.

TABLE 11.—*Export value compared with pit's mouth value for the years 1919 to 1928.*

Year.	Declared export value per ton.		Value at the pit's mouth, per ton.	
	Rs.	A.	Rs.	A.
1919	11	14	4	5
1920	12	13	5	1
1921	13	15	6	10
1922	13	8	7	10
1923	17	2	7	7
1924	16	9	7	1
1925	15	0	6	0
1926	12	14	4	12
1927	12	2	4	2
1928	11	9	3	12

An examination of the statistics relating to the production of coal in India shows that there has been a more or less general increase, year by year, since the sharp fall in 1920. The output in 1928 is almost equal to that of the record year 1919, and it is probable that the total production in 1929 will exceed it. It is true that Burma has ceased to be a producer of coal, and that the production of Baluchistan has fallen somewhat appreciably, Assam shows a smaller output than in 1919 to 1923. In the case of Baluchistan the cause is directly due to the closing down of Khost colliery. The demand for Punjab coal has not been brisk, due largely to the relatively lower prices at which Bengal coal has recently been offered. In Hyderabad the increased output appears to be encouraging, as new pits were being sunk and a new area opened up. Assam coal has suffered slightly in competition with petroleum due to several tea gardens adopting oil engines for power purposes. The rise in output from Central India has been in spite of competition with Bengal coal. Notwithstanding the closing down of a few collieries in the Central Provinces there has been a general im-

TABLE 12.—*Production of Coal in the four largest British Dependencies for the years 1917 to 1927.*

Countries.	1917 Long Tons	*Per cent. of British output.*	1918 Long Tons	*Per cent. of British output.*	1919 Long Tons	*Per cent. of British output.*	1920 Long Tons	*Per cent. of British output.*	1921 Long Tons	*Per cent. of British output.*	1922 Long Tons	*Per cent. of British output.*
India	18.212,918	*5·99*	20.722.493	*7·00*	22 628,037	*7·86*	17.962,214	*6·20*	19,302.047	*8·60*	10,010.986	*5·61*
Australia	10,236,666	*3·36*	10,949,346	*3·69*	10.566.724	*3·66*	12 968.352	*4·49*	12 877.526	*5·80*	12,299,019	*3·63*
Canada	12,542,000	*4·12*	13,373,000	*4·51*	12.215,000	*4·24*	14.842,000	*5·14*	13.444.189	*6·06*	13,533,000	*4·00*
South Africa . . .	9,776.058	*3·21*	9,308,008	*3·14*	9.691.638	*3·37*	10.749.934	*3·72*	10,644,812	*4·79*	9,125,000	*2·69*
Total for British Empire† .	**303,873,000**	..	**296,629,000**	..	**288,000.000**		**289,000.000**	.	**222,000,000**	..	**338,590,000**	..

† Approximate

Countries.	1923 Long Tons	*Per cent. of British output.*	1924 Long Tons	*Per cent. of British output.*	1925 Long Tons	*Per cent. of British output.*	1926 Long Tons	*Per cent. of British output.*	1927 Long Tons	*Per cent. of British output.*
India	19,656.883	*5·82*	21.174,284	*6·39*	20,904,377	*6·83*	20,099.167	*10·88*	22,082,336	*6·91*
Australia	12,631,000	*3·73*	13,757,500	*4·16*	13,626.777	*4·45*	13,250.000	*6·86*	(*a*)	..
Canada	15.170,000	*4·49*	8,995.000	*2·41*	8,491.000	*2·77*	11.491.000	*5·95*	12.135.000	*4·10*
South Africa . . .	11,125,000	*3·29*	11,153,000	*3·37*	11.607 000	*3·79*	12.262,000	*6·35*	(*b*) 11.872,000	*3·71*
Total for British Empire† .	**338,000,000**	..	**331,000,000**	..	**306,000,000**	..	**193,000,000**	..	**320,000,000**	..

(*a*) Not available. (*b*) Figure for coal sold. † Approximate.

provement in the coal trade from that region. And in the case of the Damuda valley coal-fields there has been a marked increase in total production although many small collieries, engaged in working the poorer grade seams, have been obliged to close down. From available figures India, as regards her coal trade, is in a better position than South Africa and Australia, but falls behind Japan.

TABLE 13.—*Comparison of Indian and Japanese Coal statistics.*

Year.	PRODUCTION.		IMPORTS.		EXPORTS.		Quantity retained for consumption in Japan.
	India.	Japan.	India (*a*)	Japan.	India (*a*)	Japan.	
1885 .	1,294,221	1,294,000	790,930	12,876	750	191,802	1,115,074
1890 .	2,168,521	2,566,551	784,664	12,301	26,649	853,720	1,725,132
1895 .	3,540,019	4,783,861	761,996	68,931	81,126	1,376,068	3,426,724
1900 .	6,118,692	7,369,068	135,640	108,593	490,491	2,402,785	5,074,876
1905 .	8,417,739	11,407,799	197,784	320,495	783,051	2,507 527	9,220,767
1909 .	11,870,064	14,732,970	490,421	129,858	568,940	2.798,563	12,064.265
1913 .	16,208,009	20,973,384	644,934	567,502	760,210	3,808,394	17,732,192
1918 .	20,722,493	27,578,952	54,346	755,452	74,466	2,161,727	26,172,677
1919 .	22,628,087	30,767,537	48,675	688,402	508,635	1,968,343	29,487,396
1920 .	17,962,214	28,775,369	39,727	796,892	1,224,872	2,095,305	27,476,956
1921 .	19,302,947	26,220,617	1,090,749	777,255	277,852	2,387,709	24,610,163
1922 .	19,010,986	27,256,505	1,220,639	1,168,524	150,055	1,690,699	26,734,330
1923 .	19,656,883	28,483,571	624,918	1,658,783	182,606	1,549,004	28,593,350
1924 .	21,174,284	29,626,902	468,716	1,979,978	272,436	1,711,292	29,895,588
1925 .	20,904,377	30,953,817	483,160	1,740,500	267,026	2,694,515	29,999,802
1926 .	20,999,167	30,921,479	193,908	2,012,526	661,711	2,590,316	30,343,689
1927 .	22,082,336	32,425,285	248,603	2,660,556	620,135	2,173,449	32,912,392

(*a*) Excludes Government stores.

Nearly 98 per cent. of the Indian output of coal is consumed in this country, and as the production of coal has increased so the consumption has grown, although it is still below the amount consumed in India in 1919. The largest consumers of Indian coal are the railways an increase of over a million tons being evident between 1922 and 1927. There has been a falling off in the demand from cotton mills, but this is almost exactly offset by the increased tonnage of bunker coal. Perhaps the most attractive increase is in the supply for metallurgical purposes, and iron and steel smelting in particular. The requirements of these iron works are now more than double what they were five years ago. There has been a slight improvement as regards the consumption of coal at collieries— a smaller quantity being now reported, but this is largely due to several collieries having closed down. The amount of coal recorded from other forms of industrial and domestic consumption is less than half the figure of five years ago. The increased quantity of coal carried by the railways is an indication of the larger demand for coal in India.

TABLE 14.—*Relation of consumption to production* (*a*).

Year.	Total consumption of coal in India.	Consumption of Indian coal in India.	
		Quantity.	*Percentage of Indian production.*
	Tons.	Tons.	
1919	22,168,495	22,118,893	*97·7*
1920	16,776,083	16,735,215	*93·2*
1921	20,122,242	19,025,453	*98·6*
1922	20,182,555	18,933,243	*99·6*
1923	20,163,705	19,520,292	*99·3*
Average .	*19,882,616*	*19,266,619*	*97·7*
1924	21,463,351	20,966,836	*99·0*
1925	21,203,429	20,687,449	*98 9*
1926	20,593,497	20,380,465	*97·1*
1927	21,754,749	21,503,835	*97·4*
1928	22,145,212	21,913,056	*97·2*
Average .	*21,432,048*	*21,090,328*	*97·9*

(*a*) The consumption of coal is assumed to be production *plus* imports *minus* exports. In the exports and imports a ton of coke is taken to be equivalent to 2 tons of coal. The imports exclude Government stores.

TABLE 15.—*Estimated consumption of coal in India during the years 1922 and 1927.*

——	Estimated Consumption in 1922-23.	*Per cent. of total.*	Estimated consumption in 1927-28.	*Per cent. of total.*
	Tons.		Tons.	
Railways . . .	6,186,000(*a*)	*30·8*	(*a*)7,259,000	*33·5*
Admiralty and Royal Indian Marine.	40,000	*0·2*	27,000	*0·1*
Bunker coal . .	796,000	*4·0*	1,317,000	*6·1*
Cotton mills . .	1,131,000	*5·6*	830,000	*3·8*
Jute mills . .	942,000	*4·7*	935,000	*4·3*
Iron industry (including engineering work-shops).	2,415,000	*12·0*	5,260,000	*24·2*
Port Trusts . .	210,000	*1·1*	205,000	*0·9*
Inland steamers . .	582,000	*2·9*	636,000	*2·9*
Brick kilns, potteries, cement works, etc.	437,000	*2·2*	565,000	*2·6*
Tea gardens . .	204,000	*1·0*	223,000	*1·0*
Paper mills . .	147,000	*0·7*	156,000	*0·7*
Collieries and wastage .	2,471,000	*12·3*	2,208,000	*10*
Other forms of industrial & domestic consumption.	4,521,000(*b*)	*22·5*	2,085,000	*9·7*
TOTAL .	20,082,000	*100·0*	21,706,000	*100·0*

(*a*) For the official years 1922-23 and 1927-28.

(*b*) This figure appears high but it includes many classes of establishments and factories which are worked by steam power, such as cotton gins and presses, jute presses, rice and flour mills, dock yards, oil mills, water works, electric power stations, gas works, tramways, gold and other mines, sugar factories, lime kilns, breweries and distilleries, ice and aerated water factories, mints, municipal workshops, flour mills, woollen mills, chemical works, dye works, rope works, glass works, lac and indigo factories, etc. A certain amount of coke is used for domestic consumption and its use is extending owing to the growing scarcity and increasing cost of wood fuel.

TABLE 16.—*Coal consumed on Indian Railways during the years 1918-19 to 1927-28.*

Year.	INDIAN COAL.		FOREIGN COAL.		TOTAL CON-SUMPTION.
	Quantity.	*Per cent. of total.*	Quantity.	*Per cent. of total.*	
	Tons.		Tons.		Tons.
1918-19 . . .	5,880,165	*100*	964	..	5,881,129
1919-20 . . .	6,055,492	*100*	860	..	6,056,352
1920-21 . . .	6,287,068	*100*	586	..	6,287,654
1921-22 . . .	5,478,902	*88·5*	710,066	*11·5*	6,188,968
1922-23 . . .	5,476,041	*88·5*	710,329	*11·5*	6,186,370
Average .	*5,835,534*	*95·4*	*284,561*	*4·6*	*6,120,095*
1923-24 . . .	6,060,693	*98·0*	123,361	*2·0*	6,184,054
1924-25 . . .	6,605,446	*99·5*	33,493	*0·5*	6,638,939
1925-26 . . .	6,550,241	*99·8*	12,835	*0·2*	6,563,076
1926-27 . . .	6,433,284	*99·9*	4,597	*0·1*	6,437,881
1927-28 . . .	7,257,623	*99·9*	1,804	*0·1*	7,259,427
Average .	*6,581,457*	*99·4*	*35,218*	*0·6*	*6,616,675*

TABLE 17.—*Coal carried for the Public in India and for Foreign Railways during the years 1918-19 to 1927-28.*

Year.	Coal carried on Indian Railways.	Earnings of Railways from coal Traffic.
	Millions of Tons.	Rs. Million.
1918-19	23·25	88·04
1919-20	21·40	79·08
1920-21	21·86	82·14
1921-22	18·78	72·99
1922-23	20·37	85·30
1923-24	19·85	82·23
1924-25	22·85	91·65
1925-26	22·01	89·54
1926-27	23·91	90·37
1927-28	25·78	95·03

When we study the data on Indian imports and exports of coal there is seen to be a very satisfactory balance of trade in favour of India as regards tonnage. The imports, a little over 200,000 tons in 1928, are roughly ⅓ of the exports. It is believed that this satisfactory trend of the coal trade is due to the strict observance of quality in the export of Indian coal. And to the same factor must be ascribed the gradual replacement of foreign coal by Indian coal in the Indian market. The only serious competitor in India is the coal imported from South Africa, particularly from Rhodesia *viâ* Beira. It appears likely that, with careful attention to quality and the reduction in freight recently granted by the State Railways, the imports of foreign coal will be further reduced by substitution from Indian sources. The improvement in the export trade can be gauged by the imports into Ceylon and the Straits Settlements. In the former case India and South Africa are each striving to monopolise the trade but so far the imports are about equally divided between them. In the Straits Settlements the market is supplied from several sources but South Africa and Japan have a considerable share in the trade, with Dutch Borneo and Sumatra also attractively engaged. Nevertheless in this market Indian coals have been imported in rapidly increasing quantities and exceed the supplies despatched from Sumatra. The trend of the trade shows that Indian coal is actually displacing the coals from Japan and South Africa.

TABLE 18.—*Indian imports and exports* of Coal during the years 1914 to 1928.*

Year.	Imports.	Exports.
	Tons.	Tons.
1914	418,758	579,746
1915	190,654	753,042
1916	34,033	881,741
1917	44,818	408,117
1918	54,346	74,466
1919	48,675	508,537
1920	39,727	1,224,758
1921	1,090,749	275,571
1922	1,220,639	77,111
1923	624,918	136,575
Average 1914-1923	*376,732*	*491,966*
1924	463,716	206,483
1925	483,160	216,090
1926	193,908	617,563
1927	243,603	576,167
1928	210,186	626,343
Average 1924-1928	*318,914*	*448,529*

* Excluding bunker coal and Government stores; but including coke and patent fuel.

TABLE 19.—*Origin of Foreign Coal (a) imported into British India*

YEAR.	United Kingdom.	Australia.	Union of South Africa.	Japan.	Portuguese East Africa.	Other Countries.	Total.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Total
1919	5,643	3,329	18,089	927	16,880	3,807	48,675
1920	5,022	8,134	7,835	1,302	7,033	6,411	39,727
1921	441,305	111,384	306,068	68,071	156,555	6,466	1,090,749
1922	742,469	17,849	236,034	55,547	157,122	11,618	1,220,639
1923	131,739	59,380	281,793	4,660	115,942	31,404	624,918
Average	*265,236*	*40,015*	*170,144*	*26,719*	*90,887*	*11,941*	*604,942*
1924	109,916	21,803	185,141	2,384	141,537	2,935	463,716
1925	124,111	7,495	204,180	7,470	130,312	9,583	483,160
1926	35,142	13,323	89,911	7,229	46,194	2,109	193,908
1927	55,903	11,017	133,827	5,869	29,314	7,673	243,603
1928	40,233	5,321	129,734	380	31,577	2,941	210,186
Average	*73,061*	*11,792*	*148,560*	*4,666*	*75,787*	*5,048*	*318,914*

(a) Excluding Government stores but including coke.]

TABLE 20.—*Exports of Indian Coal* (*a*).

	1919	1920	1921	1922	1923	*Average.*
	Tons.	Tons.	Tons.	Tons.	Tons.	*Tons.*
Aden	13,525	83,669	17,576	..	..	*22,954*
Ceylon	206,192	685,559	236,615	76,742	119,620	*282,951*
Java	17,106	16,083	..	50	100	*6,686*
Straits Settlements	116,304	228,365	11,373	..	1[illegible],388	*74,284*
Sumatra	41,756	69,473	6,251	..	..	*23,496*
Other countries	23,561	(*e*)141,619	3,726	319	1,467	*34,139*
Total Exports	**508,537**	**1,224,758**	**275,571**	**77,111**	**136,575**	*441,510*
Value in Rs.	60,38,110	1,57,13,040	38,47,395	10,62,133	23,41,960	*58,00,587*
Value in Sterling	£525,053 (£1 = Rs. 11 5)	£1,571,304 (£1 = Rs. 10)	£256,493 (£1 = Rs. 15)	£70,820 (£1 = Rs. 15)	£156,131 (£1 = Rs. 15)	*£515,962*

	1924	1925	1926	1927	(*b*) 1928	*Average.*
	Tons.	Tons.	Tons.	Tons.	Tons.	*Tons.*
Aden	7,423	..	50,342	2	.	*13,353*
Mauritius	..	1,665	..	1,555	1,700	*981*
Straits Settlements	17,763	18,751	117,469	147,405	73,389	*74,956*
Sumatra	..	612	4,049	15,568	..	*4,046*
Hongkong	.	..	2,085	8,752	110,701	*24,308*
Ceylon	170,701	194,189	243,263	341,352	352,602	*260,421*
Other Countries	10,596	870	(*c*)191,355	61,533	(*d*)87,951	*70,461*
Total Exports	**206,483**	**216,090**	**617,563**	**576,167**	**626,343**	*448,529*
Value in Rs.	34,19,008	32,44,091	79,33,246	69,76,113	72,47,597	*57,64,029*
Value in Sterling	£245,078 (£1 = Rs. 13·9)	£243,917 (£1 = Rs. 13·3)	£592,033 (£1 = Rs. 13·4)	£520,605 (£1 = Rs. 13·4)	£540,865 (£1 = Rs. 13·1)	*£428,679*

(*a*) Excluding bunker coal and Government stores but including coke and patent fuel.
(*b*) Excludes figures for patent fuel
(*c*) Includes 105,711 tons shipped to Egypt and 51,363 tons to the United Kingdom.
(*d*) Includes 72,087 tons shipped to Philippine Islands and Guam.
(*e*) Includes 102,457 tons shipped to Egypt.

TABLE 21.—*Quantity of coal, coke and patent fuel, exported from Calcutta to Indian Ports during the years 1919 to 1928.*

PORTS.	1919	1920	1921	1922	1923	*Average.*
	Tons.	Tons.	Tons.	Tons.	Tons.	*Tons.*
Bombay	25,458	136,852	610,181	82,156	100,755	*251,080*
Sind	..	75,990	115,341	28,791	62,095	*(a)56,444*
Madras; chief port	22,354	105,358	197,130	180,905	194,602	*140,070*
Madras; other ports	8,899	25,387	178,318	175,856	16,086	*80,909*
Burma; chief port	122,769	359,864	117,120	308,727	459,353	*333,567*
Burma; other ports	8,674	9,462	10,788	8,956	13,164	*10,209*
Bihar and Orissa	74	318	418	178	287	*255*
Bengal; all ports	55	17,099	34,891	22,199	9,898	*16,828*
Pondicherry	1,671	..	600	..	..	*(a)454*
Kathiawar; Dwarka	..	..	29,833	..	..	*(a)5,967*
Kathiawar; Porbunder	..	..	1,822	..	..	*(a)364*
TOTAL	**189,954**	**1,030,330**	**1,596,442**	**807,771**	**856,240**	*896,117*

(*a*) Average for five years.

PORTS.	(*b*) 1924	1925	1926	1927	1928	*Average.*
	Tons.	Tons.	Tons.	Tons.	Tons.	*Tons.*
Bombay	174,355	202,759	319,855	349,211	282,111	*271,724*
Sind	61,379	97,773	170,671	154 692	138,915	*124,692*
Madras	250,885	201,209	352,985	116,797	471,523	*357,298*
Burma	282,870	133,705	529,780	776,546	690,487	*542,678*
Bihar and Orissa	205	37	3,866	1	1	*812*
Bengal	16,416	15,414	10,008	20,351	24,531	*17,344*
Indian ports not British	..	7,341	60,585	42,692	87,054	*39,534*
TOTAL	**786,110**	**1,051,328**	**1,477,750**	**1,760,290**	**1,694,982**	*1,354,092*

(*b*) For 9 months—April to December 1924; figures for the months of January to March 1924 are not available.

TABLE 22.—*Foreign coal imports of Ceylon for the years 1919 to 1928.*

ORIGIN OF THE COAL.	1919	1920	1921	1922	1923	*Average.*
	Tons.	Tons.	Tons.	Tons.	Tons.	*Tons.*
United Kingdom	2,104	6,165	129,568	240,516	166,968	*109,064*
British India	538,741	744,690	275,893	72,858	124,414	*351,319*
Japan	23,602	8,928	28,313	5,815	80	*13,348*
Other countries	171,675	49,358	281,601	262,527	253,086	*203,649*
TOTAL Imports	**736,122**	**809,141**	**715,375**	**581,716**	**544,548**	*677,380*

ORIGIN OF THE COAL.	1924	1925	1926	1927	(a)1928	*Average.*
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
United Kingdom	182,037	141,337	76,397	113,710	81,716	*119,039*
British India	167,590	204,680	224,132	337,400	335,194	*253,859*
British South Africa	310,762	321,442	326,930	260,831	203,026	*284,598*
Other countries	14,447	4,695	35,927	30,446	25,044	*22,112*
TOTAL Imports	**675,136**	**672,154**	**663,386**	**742,387**	**644,980**	*679,608*

(*a*) Excludes Government stores.

TABLE 23.—*Foreign coal imports of the Straits Settlements for the years 1919 to 1927.*

Year.	From United Kingdom.	From British India.	From Australia.	From Japan.	From Union of South Africa.	From Dutch Borneo.	From Sumatra.	From other countries.	Total.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1919	693	87,066	64,543	271,326	34,634	12,316	2,385	30,078	**503,041**
1920	151	188,432	138,472	341,195	5,317	21,281	3,680	28,173	**726,701**
1921	10,364	12,493	92,941	340,007	11,656	17,117	1,600	54,882	**541,060**
1922	90,583	..	67,277	226,646	76,501	17,336	11,158	94,913	**584,414**
1923	33,888	21,984	34,965	176,692	153,807	68,101	60,104	84,211	**633,752**
Average 1919-1923	*27,136*	*61,995*	*79,640*	*271,173*	*56,383*	*27,230*	*15,785*	*58,451*	***597,793***
1924	44,178	6,955	79,497	52,969	265,799	80,613	55,750	109,454	**695,215**
1925	38,052	18,749	31,676	134,710	176,702	94,904	54,833	99,947	**649,573**
1926	12,283	111,913	14,759	236,611	163,148	124,165	60,658	75,557	**792,094**
1927	59,594	136,001	25,276	200,421	182,102	174,365	48,488	44,722	**873,946**
Average 1924-1927	*38,527*	*68,404*	*38,552*	*156,178*	*196,938*	*118,512*	*54,927*	*82,420*	***754,458***

Looked at broadly the question of the future of the Indian coal trade—its expansion both in volume and monetary value - is most complex. The markets for coal outside India, on the Indian Ocean and western Pacific seaboard, do not absorb more than a fraction of the Indian output, but they will be valuable to the Indian coal vendor until a better market can be obtained. There seems to be little doubt that greater expansion of the Indian coal trade could be brought about by the cultivation of a demand for coal as household fuel in this country. When it is remembered that the population of India is 300 millions and that barely 2 million tons of coal are used for household purposes the potentialities of this trade appear attractive. It is, however, well known that any considerable measure of success in this direction involves long and expensive effort. The people are poor, wood and dung are obtainable free, so that it would be unreasonable to expect them to use coal unless this was supplied free. There are some areas, Eastern Bengal and Berar, where a smokeless fuel will sell, and it is in these that a beginning can be made. At present only the inferior grade (high ash) coals are used in the manufacture of smokeless fuel or soft coke. It is also true that the best quality coking coals are being used for steam raising purposes—in power stations and locomotives. It is probable that the successful application of pulverised fuel firing in boilers and cement kilns will lead to some economy in the use of coking coal. The adoption of low temperature distillation (carbonisation) of coal may, when commercially successful, be of considerable value to the Indian coal industry.

II.—Geological Relationships.

Coal in workable seams is known to occur in India at various horizons among the rocks of the Peninsula and in the Extra-Peninsular regions of Burma, Assam, the Himalaya and Baluchistan. The most important coal seams are of course those in the Lower Gondwana (Permian) strata of the Peninsula and in the Tertiary (Miocene) rocks of Upper Assam. Roughly 98 per cent. of the Indian production of coal is obtained from the Lower Gondwana coal seams, and the remainder is obtained from rocks of Tertiary age. No coal is now obtained from the Jurassic strata of the Loi-an (Kalaw) field of the S. Shan States nor from the Pleistocene lignites of Nam-ma

and Lashio in the N. Shan States of Burma. A list of the potential coal measures of India is shown below :—

	Coal-field.	Geological Age.	
12.	Nam-ma, etc., N. Shan States, Burma	Pleistocene.	
11.	Makum, Nazira, Naga Hills, Up. Assam	Miocene.	Tertiary.
10.	Cherrapunji, Khasia Hills, Assam	Up. Eocene.	
9.	Kalewa, Chindwin river, Burma.	Lr. Eocene.	
8.	Palana, Bikaner State, Rajputana		
7.	Dandot, Punjab Salt Range, Khost, Sor Range, etc.. Baluchistan		
6.	Kalakot, Jammu State, Kashmir		
5.	Darenggiri, etc., Garo Hills, Assam	Cretaceous.	Mesozoic.
4	Loi-an, S. Shan States, Burma	Jurassic	
3.	Raniganj series seams of Raniganj and Jharia	Up. Permian	Lower Gondwana.
2.	Barakar series seams of Jharia and other Peninsular fields.	Lr. Permian.	
1.	Karharbari seam, Giridih coal-field		

Typical analyses of the above mentioned coals are given in the accompanying columns : —

	Coal field.	Moisture.	Volatile matter.	Fixed carbon.	Ash.
		Per cent.	Per cent.	Per cent.	Per cent.
12.	Namma, Burma	8·98	44·84	44·25	1·93(*a*)
	,, ,,	23·74	36·50	36·36	3·40(*b*)
11.	Makum, Assam	2·04	42·27	54·27	1·21(*c*)
	Nazira, Assam	4·35	48·00	45·70	1·95(*d*)
	Naga Hills	8·15	38·48	52·98	0·39(*e*)
10.	Cherrapunji, Assam	2·14	50·38	42·71	2·77
9.	Kalewa, Burma	9·82	45·19	42·58	2·41(*f*)
8.	Palana, Rajputana	12·55	46·67	36·38	4·40(*g*)
7.	Dandot, Punjab	6·13	36·81	47·17	9·89
	Mach, Baluchistan	10·71	41·43	45·68	2·18(*h*)
	Khost, Baluchistan	2·29	41·51	46·52	9·68
6.	Kalakot, Jammu	0·43	12·45	78·12	9·00(*i*)
	Kalakot, Jammu	4·14	15·92	68·26	11·68
5.	Waimong, Garo Hills	1·49	51·32	40·98	6·21(*j*)
	Dogring, Garo Hills	4·86	33·80	56·13	5·71(*k*)
4.	S. Shan States, Burma	1·22	29·88	62·51	6·39(*l*)
3.	Raniganj, Ghusick	7·55	34·80	52·60	12·60(*m*)
	Raniganj, Disheirgarh	2·57	33·25	54·25	9·80(*m*)
2.	Jharia, No. XIII	1·80	28·80	59·30	11·90(*m*)
	Jharia, No. XIV	1·27	22·85	64·70	12·45(*m*)
	Jharia, No. XII	0·75	20·10	65·30	14·60(*m*)
	Jharia, No. V-VI	0·65	14·10	66·20	19·80(*m*)
1	Giridih, Karharbari	0·90	22·50	66·00	10·60

Remarks—(*a*) Sp. Gr. 1·38, (*b*) As taken, (*c*) Namdang, (*d*) Borjan, (*e*) Wakching, (*f*) Sp. Gr. 1·3z, (*g*) Dark-brown, (*h*) Picked, (*i*) Near Ber, (*j*) Coking, (*k*) Non-coking, (*l*) Coking. (*m*) Moisture free, Alipur Test House analyses.

The statistical data regarding the origin of the annual production of coal in India is given in the following Tables :—

(24) Total Indian coal from Lower Gondwana and Tertiary strata during the years 1919 to 1928.

(25) Detailed production of coal from Lower Gondwana coal-fields for the years 1919 to 1928.

(26) Detailed production of coal from Tertiary coal-fields during the years 1919 to 1928.

TABLE 24.—*Origin of Indian Coal raised during the years 1919 to 1928.*

—	From Gondwana Strata.		From Tertiary Strata.		Total production
	Tons.	Per cent. of total.	Tons.	Per cent. of total.	Tons.
1919 . .	22,238,802	*98·28*	389,235	*1·72*	22,628,037
1920 . .	17,526,444	*97·58*	435,770	*2·42*	17,962,214
1921 . .	18,844,092	*97·62*	458,855	*2·38*	19,302,947
1922 . .	18,520,513	*97·43*	490,473	*2·57*	19,010,986
1923 . .	19,217,176	*97·77*	439,707	*2·23*	19,656,883
Average . .	*19,269,405*	*97·71*	*442,808*	*2·26*	*19,712,213*
1924 . .	20,696,338	*97·75*	477,946	*2·25*	21,174,284
1925 . .	20,447,898	*97·82*	456,479	*2·18*	20,904,377
1926 . .	20,583,202	*98·02*	415,965	*1·98*	20,999,167
1927 . .	21,664,488	*98·11*	417,848	*1·89*	22,082,336
1928 . .	22,153,314	*98·27*	389,558	*1·73*	22,542,872
Average . .	*21,109,048*	*97·99*	*431,559*	*2·01*	*21,540,607*

Gondwana (fresh-water) coal deposits.

The richest workable coal seams in India are of course those of the Lower Gondwana period in the coal-fields of the Damuda valley

and other areas in the Peninsula. In their type area, the Damuda or coal-bearing series are nearly 7,000 feet thick. In the Jharia field, in the lowest stage (Barakar) of this series, there are no less than eighteen workable seams, totalling nearly 200 feet of coal. In the upper stage (Raniganj), of the Raniganj field there are roughly six workable seams of a total thickness of, roughly, 50 feet of coal. In both stages the seams are interbedded between shales (usually below) and sandstones (frequently above). The sandstones are often coarse and conglomeratic, with, in many cases, the pebbles resting on the coal. There are numerous instances of current-bedding and overstepping of the sandstones and shales on to the coal seams. The seams are laminated and well-bedded, even when more than forty feet thick. When traced in one or other direction the coal seams are found to split or come together. It is not unusual to find a coal seam passing laterally into carbonaceous shale.

These coal-bearing strata are clearly sediments which have been deposited in fresh-water, either in wide river valleys or in extensive and shallow (?) lakes. Except in the single case at Umaria in South Rewah, no marine fossils are found associated with the Lower Gondwanas in the Peninsula. There is a remarkable paucity of animal remains of any kind in these coal-measures. On the other hand, the strata contain a rich fossil flora of terrestrial plants- stems, leaves and seeds. The silicified trunks of trees and fossil-wood are present in some of the sandstones. Tree stems, with the outer or cortical portion converted into bright coal, are met with in the roofs of some seams. Only in one case have the remains of large vertebrates been found in strata of the Damuda group, but there are several instances of reptilian and amphibian remains being found in the strata of the next series, Panchet, above those of the Damuda epoch. The evidence as a whole is suggestive of the coal-seams being true sediments- of detrital vegetable matter. It is difficult to say definitely if the vegetable material drifted from a distance or accumulated in the marshes and swamps around which the plants lived and died.

There is a considerable range in the variety of the coals obtained from the numerous seams in the Jharia coal-field. These differ in geological age, from Lower Permian, for the basal (numbers I to X) seams of the Barakar series, to Upper Permian, for the seams in the Raniganj series of the same field. When these seams are compared with each other and with the seams of the Raniganj series in the

Raniganj field, remarkable differences of character are found, which, to some extent, may be evident from the analyses given below :—

Gondwana Coals.[1]

—		Moisture.	Volatile matter.	Fixed carbon.	Ash.
Jharia, Barakar series.		Per cent.	Per cent	Per cent.	Per cent.
Matiagara (II)	Seam	0·65	14·2	68·0	17·8
Narkharki (V)	,,	0·65	14·1	66·2	19·7
Dhansar (VIII)	,,	1·0	17·3	61·57	21·13
Dhanajoba (X)	,,	1·0	19·0	62·4	13·6
Kenwadih (XII)	,,	0·75	20·1	65·3	14·6
Khas Jharia (XII)	,,	1·15	21·65	62·35	16·0
Bhuggutdih (XIV)	,,	1·27	22·85	64·7	12·45
Lodna (XIV)	,,	1·6	24·6	61·0	14·4
Bhagaband (XVI)	,,	1·3	24·5	60·2	15·3
Bhagaband (XVII)	,,	1·6	27·2	59·6	13·2
Bhutgoona (XVII)	,,	2·0	28·13	58·85	13·02
Noonudih (XVIII)	,,	1·80	28·8	59·3	11·9
Jamadoba (XVIII)	,,	1·70	28·10	56·80	15·10
Jharia, Raniganj series.					
Murulidih		2·2	29·30	57·00	43·2
Bhatdih		1·7	31·0	54·5	14·5
Huntodih (top)		2·07	32·2	52·75	15·05
N. Pipratanr		1·97	32·0	53·3	14·7
West Raniganj—Raniganj series.					
Nursamuda		6·1	33·3	52·1	14·6
Dadka		5·3	32·6	53·7	13·7
Ragnathbati		3·9	31·0	57·9	11·1
Dishergarh		2·57	33·95	54·95	11·1
Hatnal		2·15	31·05	48·9	20·05
Sanctoria		2·81	32·0	59·0	9·0
East Raniganj—Raniganj series.					
Ghusick		7·55	34·8	52·6	12·6
Nega		6·4	32·1	53·65	14·25
Searsole		7·5	31·1	52·3	16·6
Bowla		8·3	33·8	54·7	11·5
Joba		5·5	31·5	55·7	12·8
Koithi		4·7	33·2	53·7	13·1
Poniati		4·85	32·83	55·8	11·35
Poniati		6·0	30·7	59·9	9·4
Poniati		8 8	30·0	59·1	10·9
Samla		11·0	31·5	57·1	11·4
Taltore		6·3	29·6	55·0	15·4

N.B.—All analyses are of samples collected by officers of the Coal Grading Board. Analyses made at Government Test House, Alipur, Calcutta.

[1] Results given above are on a moisture-free basis. All the Jharia coals coke. Seams XII to XVIII give a hard coke. The Raniganj seams are generally non-coking except Dishergarh and Sanctoria.

The above analyses show the variation in the quality of the coals in the Jharia and Raniganj coal-fields. These are the most important coal-fields in India. Both have recently been resurveyed by the Geological Survey of India and new geological maps on a scale of 4 inches to the mile have recently been published. A revised memoir on the geology of the Jharia coal-field is now in the press, while the memoir on the Raniganj field is being re-written. It will be seen, however, from Table (25) that there are at least twenty other Gondwana coal-fields in the Indian Peninsula. As the memoir on the Coal-fields of India is also being revised and the new edition will be published in a year it appears unnecessary to discuss these several fields in detail in this quinquennial review of the coal industry. The production of coal from each of these fields, given in Table (25), will be an indication of the development. It must be mentioned, however, that entirely new areas are shortly to be opened—two in particular are expected to produce coal within a few months. These are (1) the Chirmiri coal-field in Korea State, and (2) the Tandur coal-field in the Nizam's dominions (Hyderabad). During the past five years at least three new coal-fields have actually been opened and have been producing coal. These are (1) the Karanpura coal-field in the Damuda valley of Bihar, (2) the Talchir coal-field in the valley of the Brahmani in Orissa, and (3) the Wun coal-field of Yeotmal in the Wardha valley. In two areas the collieries have closed down; these are (1) the Mohpani and (2) Shahpur coal-fields in the Satpura region of the Central Provinces.

The Gondwana system in the Indian Peninsula comprises the following formations:—

	Lr. Cretaceous	Umia plant beds.		Upper Gondwanas.
Jurassic	Up. Jurassic	Jabalpur stage.		
	Mid. Jurassic	Kota (Chaugan) stage		
	Lr. Jurassic	Rajmahal (inter-trappean) plant beds.		
Trias	Rhaetic	Parsora stage.		
	Keuper	Maleri stage.		
	Bunter	Maitur stage.	Panchet series	Lower Gondwanas.
Permian	Up. Permian	Raniganj series	Damuda group	
	Mid. Permian	Barren measures.		
	Lr. Permian	Barakar series with Karharbari stage and Umaria marine beds.		
	Up. Carboniferous	Talchir series with glacial boulder bed.		

The coal measures in all the Gondwana coal-fields are restricted to the Barakar series with its basal Karharbari stage. In the Raniganj and Jharia coal-fields there are valuable seams in the Raniganj series, in fact, these constitute the most important coal-measures in the Raniganj coal-field. It is believed that the coal measures of the Darjeeling Himalaya also belong to the Raniganj series. The details of the sub-divisions in the Damuda group of the type areas Raniganj and Jharia are shown below :—

	Raniganj coal-field.	Jharia coal-field.	
Raniganj series 3,300 feet	Kumarpur sandstones.	Lohpiti sandstones.	Raniganj series 1,840 feet.
	Nituria coal-measures.	Telmucha coal-measures.	
	Hijuli sandstones.	Jamdiha sandstones.	
	Sitarampur coal-measures.	Muralidih coal-measures.	
	Ethora sandstones.	Mahuda sandstones.	Barren measures 2,080 feet.
Ironstone shales 1,200 feet	Ironstone (Kulti) shales.	Hariharpur carb-shales.	
Barakar series 2,100 feet	Begunia sandstones	Petia sandstones.	
	Begunia shales.	Shibbabudih shales.	
	Begunia seam.	Sitanala seam (No. XVIII).	Barakar series 2,000 feet.
	Laikdih seam, etc.	XV to XIII seams, etc.	
	Damagaria seam.	Muraidih (1) seam.	

The Barakar series is at its best as a coal-bearing formation in the Jharia coal-field, but coal is generally found in these rocks in all the Gondwana coal-fields. The Raniganj series are at their maximum development as coal measures in the Raniganj coal-field. Workable seams of the Raniganj series are not found in the Peninsula west of the Jharia coal-field. No Karharbari stage has been identified in the Raniganj and Jharia coal-fields, but the opinion now held is that the Karharbari stage is a lower division of the Barakar series and included in it. Karharbari fossil plants are most abundant in the Giridih coal-field, but they have also been found in the Karanpura coal-field and in South Rewah and at Mohpani. Elsewhere, as in the Pench Valley, Wardha and Godavari Valleys and in the Mahanadi region, the plant fossils occurring with the coal-measures are typical Barakar forms. There is always a marked lithological change when crossing from the Damuda strata to the Talchirs. In a few localities rare plant fossils occur in the top of the Talchirs, but these are always at a much higher horizon than the glacial boulder bed. In fact the evidence indicates that the actual period of glaciation had probably passed away from those areas into which the *Glossopteris* flora had penetrated. Thus there are reasons for discrediting the belief that the *Glossopteris* flora flourished during an Ice Age under glacial conditions The Barakar

epoch, in which the *Glossopteris* flora appears to have been most prolific, was probably characterised by a damp, temperate climate.

Speaking in a strict stratigraphical sense, the top of each coal seam marks a stratigraphical 'break'. This is particularly true of the seams in the Jharia coal-field. Here pebbly sandstones, sometimes with the boulders themselves, rest on the coal. These covering beds are current-bedded in such a manner that successive layers overstep each other on to the coal. Such examples show that a marked change took place from the quiet, relatively deeper waters, in which the maturing vegetable mass lay, to the turmoil of a river in flood. A careful scrutiny of such junctions between the coal and the roof stone shows that the coaly matter was already quite firm before it was covered by later sediments. Complete conversion into coal appears to have already been accomplished before the overlying strata were deposited. Some pebbles resting on the coal are coated with coal and no such pebbles have either sunk into the coal or are deeply embedded in it. In other cases pebbles are found with their coal contact surfaces corroded evidently by subsequent percolating alkaline waters, since the pebbles were originally smooth and rounded and are of quartzite. In several cases the mine water in Indian coal mines is found to be alkaline and not acid, and this in spite of the fact that the coal contains pyritiferous matter and the water deposits limonite from the solution when exposed to air.

There is no doubt at all that the fresh water and marine coals of India were formed under water in regions subject to prolonged subsidence. The deposition of the Damuda group involved upwards of 6,000 feet of coal-bearing strata, and necessitated subsidence throughout the Permian period—of 12 to 15 million years duration. One foot of sediment in 2,000 years is a slow rate of uniform deposition under fluviatile conditions. The presence of successive beds of pebbly sandstones, followed upward by shales and succeeded by coal seams, shows that the sedimentation was not uniform, but we have no evidence in the Raniganj field, the type area of these deposits, that the pauses involved the sediments being exposed to atmospheric weathering. The data merely points to a slowing down of the velocity of the rivers and periods of relative stagnation when the plant debris settled down. The plant debris appears to have remained submerged throughout. I have stated before that the sandstones are markedly current-bedded; that some coal seams

pass laterally into shales; and that single seams split up into one or more seams when traced in a particular direction. These are evidences of fluviatile deposition.

The above features are not so clearly seen in the case of the marine (Tertiary) coal-bearing strata of Assam and Burma on the one hand and of the north-west of India on the other. The evidence from these Tertiary coal-fields is that the plant debris, again largely of terrestrial flora, was deposited in the stagnant waters of lagoons bordering deltas or at the head of a gulf. It is known that these regions were undergoing subsidence at the time of the deposition of the coal-bearing strata. It has been pointed out that the Eocene coals of the north-west, and the Salt Range of the Punjab in particular, are overlaid and underlaid by carbonaceous, pyritiferous shales in a conformable manner. These black shales are rich in the fossil remains of foraminifera. Judging by the pyritic character of the beds, the plant material must have accumulated in distinctly acid (sulphurous) water—probably excellent for the preservation of plant structures but fatal to animal life. Higher in the succession of strata there are massive nummulitic limestones which indicate the deeper waters of an open sea.

In the case of the Bikaner lignite, which failed to be converted into coal, the stratigraphical record is in general similar to that of the Salt Range, but with this very important difference—there is a well-marked, stratigraphical 'break' at the top of the lignite horizon. The lignite had been subjected to erosion in Eocene times and was then directly overlaid by the nummulitic limestone. The lapse of time indicated by the 'break' is, geologically speaking, not large, since the strata above are of Upper Eocene age—a duration of time equal only to a phase of Middle Eocene sedimentation. Measured in terms of normal time the pause may represent the lapse of centuries. The absence of coarse sediments suggests that the cause of the erosion of the lignite was exposure to atmospheric weathering, while the presence of the overlying limestone indicates a relatively sudden re-submersion—in the clear waters of the nummulitic sea. The result of this believed exposure to atmospheric conditions appears to have been that the lignitic mass was so affected (oxidised) that the processes of coal formation ceased. In spite of the subsequent return to submerged conditions the processes were arrested, and we find lignite to-day in Bikaner among strata which in adjoining regions contain coal.

TABLE 25.—*Output of Gondwana coal-fields for the years 1919 to 1928.*

—	1919		1920		1921		1922		1923	
	Tons.	*Per cent. of Indian total.*	Tons.	*Per cent. of Indian total.*	Tons.	*Per cent. of Indian total.*	Tons.	*Per cent. of Indian total.*	Tons.	*Per cent. of Indian total.*
***Bengal, Bihar and Orissa*—**										
Bokaro	722,682	*3·19*	857,522	*4·78*	929,143	*4·81*	1,037,171	*5·46*	1,060,366	*5·39*
Daltonganj	63,250	*0·28*	39,113	*0·22*	36·590	*0·19*	31,933	*0·17*	11,815	*0·06*
Giridih	950,045	*4·20*	831,293	*4·63*	818·580	*4·24*	659,101	*3·47*	713,598	*3·58*
Hutar	..	..	..	..	..	..	..	..	..	..
Jáinti	152,941	*0·69*	118,651	*0·66*	105,652	*0·55*	96,612	*0·51*	82,166	*0·42*
Jharia	12,145,917	*53·68*	9,294,040	*51·74*	10,068,856	*52·16*	9,936,299	*52·27*	10,346,015	*52·63*
Karanpura	..	..	..	..	..	..	..	..	..	..
Rajmahal Hills	1,909	..	960	..	2,170	*0·01*	2,801	*0·01*	2,635	*0·01*
Ramgarh	..	..	6,863	*0·04*	..	..	4,565	*0·02*	4,197	*0·02*
Rampur (Raigarh-Hingir).	45,574	*0·20*	36,987	*0·21*	77,277	*0·40*	68,618	*0·36*	50,796	*0·26*
Raniganj	6,815,126	*30·11*	4,997,679	*27·82*	5,211,855	*27·00*	5,203,214	*27·37*	5,557,424	*28·28*
Talchir	..	..	..	..	..	..	..	..	4,816	*0·02*
***Burma*—**										
Loi-an (Kalaw)	..	..	..	..	300	..	172	..	895	*0·01*
***Central India*—**										
Sohagpur	..	..	..	..	37.060	*0·19*	42,693	*0·22*	80,125	*0·41*
Umaria	182,141	*0·80*	158,051	*0·88*	154,974	*0·80*	118,538	*0·62*	95,825	*0·49*
***Central Provinces*—**										
Ballarpur	126,366	*0·56*	128,162	*0·71*	171,425	*0·89*	132,680	*0·70*	112,362	*0·57*
Hoshangabad	..	..	..	..	..	..	..	..	..	..
Mohpani	85,299	*0·38*	83,335	*0·47*	89,623	*0·47*	84,996	*0·45*	87,387	*0·44*
Pench Valley	285,356	*1·26*	279,483	*1·56*	449,311	*2·33*	453,484	*2·39*	346,094	*1·76*
Shahpur	..	..	..	..	210	..	1,069	*0·01*	2,063	*0·01*
Yeotmal	..	..	225	..	2,345	*0·01*	3,687	*0·02*	168	..
***Hyderabad*—**										
Sasti	..	..	27,745	*0·15*	42,674	*0·22*	38,522	*0·20*	29,204	*0·20*
Singareni	662,196	*2·93*	666,335	*3·71*	646,047	*3·35*	604,358	*3·18*	629,225	*3·21*
TOTAL Gondwana beds	22,238,802	*98·28*	17,526,444	*97·58*	18,844,092	*97·62*	18,520,513	*97·43*	19,217,176	*97·77*

TABLE 25.—*Output of Gondwana coal-fields for the years 1919 to 1928*—contd.

—	1924 Tons.	1924 *Per cent. of Indian total.*	1925 Tons.	1925 *Per cent. of Indian total.*	1926 Tons.	1926 *Per cent. of Indian total.*	1927 Tons.	1927 *Per cent. of Indian total.*	1928 Tons.	1928 *Per cent. of Indian total.*
Bengal, Bihar and Orissa—										
Bokaro	1,343,500	*6·34*	1,494,966	*7·15*	1,514,918	*7·21*	1,790,594	*8·11*	2,026,791	*8·99*
Daltonganj	4,691	*0·02*	17,274	*0·08*	9,757	*0·05*	..	..	929	*0·01*
Giridih	768,690	*3·63*	786,642	*3·76*	818,681	*3·90*	855,253	*3·87*	804,118	*3·57*
Hutar	..	..	..	..	..	..	709	..	205	..
Jainti	78,547	*0·38*	76,680	*0·37*	82,604	*0·39*	56,724	*0·26*	48,059	*0·21*
Jharia	10,845,642	*51·22*	10,676,883	*51·08*	10,373,736	*49·40*	10,583,487	*47·93*	10,665,479	*47·31*
Karanpura	..	..	13,354	*0·07*	123,867	*0·59*	262,014	*1·19*	390,493	*1·73*
Rajmahal Hills	..	..	1,653	*0·01*	1,788	*0·01*	1,488	*0·01*	636	..
Ramgarh	5,905	*0·03*	2,548	*0·01*	585	..	340	..	386	..
Rampur (Raigarh-Hingir)	49,445	*0·23*	45,410	*0·22*	29,272	*0·14*	26,895	*0·12*	31,623	*0·14*
Raniganj	6,035,347	*28·51*	5,729,686	*27·42*	6,124,884	*29·17*	6,472,036	*29·31*	6,460,490	*28·66*
Talchir	5,417	*0·03*	7,265	*0·04*	13,371	*0·07*	23,316	*0·10*	38,237	*0·17*
Burma—										
Loi-an (Kalaw)	..	..	..	..	..	..	..	..	..	..
Central India—										
Sohagpur	131,174	*0·62*	116,170	*0·55*	108,599	*0·52*	82,541	*0·37*	117,423	*0·52*
Umaria	104,124	*0·49*	102,936	*0·49*	108,109	*0·51*	135,120	*0·61*	101,327	*0·45*
Central Provinces—										
Ballarpur	127,545	*0·60*	150,490	*0·72*	142,935	*0·68*	158,617	*0·72*	175,872	*0·78*
Hoshangabad	3	..	..	..	..	..	..	..	..	..
Mohpani	76,526	*0·36*	70,039	*0·34*	71,482	*0·34*	..	..	..	..
Pench Valley	473,896	*2·24*	485,768	*2·30*	416,708	*1·98*	505,913	*2·29*	556,481	*2·47*
Shahpur	1,111	..	1,119	*0·01*	423	..	6	..	..	..
Yeotmal	..	..	1,138	*0·01*	3,704	*0·02*	2,222	*0·01*	..	..
Hyderabad—										
Sasti	25,050	*0·12*	38,153	*0·18*	28,034	*0·14*	25,477	*0·12*	35,615	*0·16*
Singareni	619,725	*2·93*	629,724	*3·01*	609,745	*2·90*	681,736	*3·09*	699,150	*3·10*
TOTAL Gondwana beds	20,696,338	*97·75*	20,447,898	*97·82*	20,583,202	*98·02*	21,664,488	*98·11*	22,153,314	*98·27*

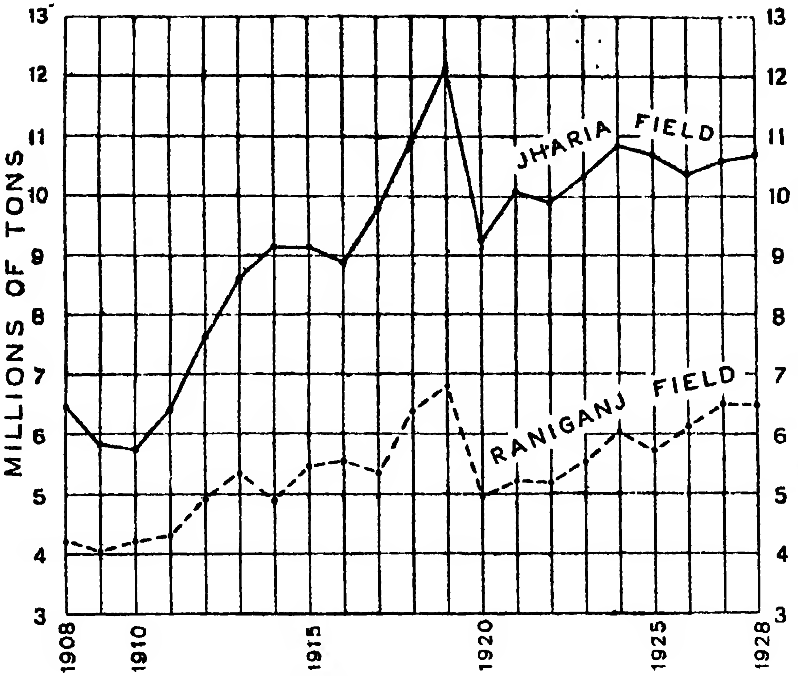

Fig. 8.—*Production of coal in the Raniganj and Jharia fields, 1908-1928.*

Tertiary (marine) Coal-seams.

In Assam the coal-measures are of Tertiary (Miocene to Oligocene) age. The seams are interbedded between shales and sandstones. Unlike the Gondwana strata, which are locally faulted and buckled, the Assam coal seams and associated rocks have been somewhat severely folded. Fossil remains are not common and, when found, are usually poorly preserved. When identifiable leaves and plant remains are obtained, they are recognised as parts of terrestrial vegetation. On the other hand the fauna is usually of invertebrate marine forms. It is generally agreed that the coal-measure series of Assam were deposited in the shallow waters of a sea—probably at the head of a gulf. This is also true of the equivalent strata, the Pegus, of Burma, in certain horizons of which coal seams also occur.

Perhaps the most interesting feature of the coal-measure series of Assam and the Pegus of Burma is the intimate association of petroleum with the coal. In Assam the intimate connection of the coal and petroleum occurrences is too obvious to escape attention. Closer observation has shown that where coal is abundant in these coal measures petroleum is scarce and *vice versâ*. Sir Edwin Pascoe[1] says:—'In Assam......in nearly every separate oil area, coal seams are found among the oil sands themselves, but it is especially in the horizons higher up that coal in any bulk is found........ Not only is there this vertical relationship, but there is another accompanying it of a geographical nature, according to which coal seams show a preference for the margins of the gulf in which the Tertiary sediments accumulated, while petroleum is usually found a little further from the coast.'

In north-west India, in Baluchistan, the Punjab Salt Range and Jammu (Kashmir), workable coal occurs in the Laki stage (Middle to Lower Eocene) of the Tertiary rocks. The seams are intercalated between pyritiferous shales and sandstones, with limestone in association. Identifiable plant remains are scarce, but the carbonised, woody parts of plants are occasionally met with in the coal. The strata above and below, and sometimes the shaley coal itself, is full of invertebrate animal remains chiefly foraminifera—all marine types. Judging by the plant remains in the lignite of Bikaner (Palana) in Rajputana, which is on exactly the same horizon (Laki stage) as the Salt Range and other coals in this region, and which were evidently accumulated in the same marine region as these black and brown Eocene coals, it appears that the vegetable matter is the debris of terrestrial plants.

The Palana lignite is characterised by the large amount of fossil resin contained in it. The coals of Baluchistan and the Salt Range also contain small amounts of resin. This is also true of the Tertiary coals of Assam. The strata in the several areas of the north-west have suffered different degrees of tectonic disturbance. The lignite beds of Rajputana barely suffered any movement at all, the Tertiary rocks of Baluchistan are folded, while the coal-bearing beds in Jammu have been involved in the orogenic movements which culminated in the uplift of the Himalaya. It is significant in this connection that the vegetable matter in the Tertiary

[1] *Mem. Geol. Surv. Ind.* XL, Pt. 2, p. 322 (1914).

rocks of Rajputana have only been converted into lignite while the coals of Jammu (Kalakot) are distinctly anthracitic.

Here again in these marine Eocene (Tertiary) strata containing coal there is an association of petroleum. The Laki stage is in particular looked upon as the petroleum horizon, which thus corresponds with the coal horizon. The two substances again show the curious features that were noticed by Sir Edwin Pascoe[1] in Assam and Burma. This authority on oil questions, while discussing the origin of petroleum generally, wrote:—'We are led to conclude that, in places where such an association can be recognised, they (coal and petroleum) were probably derived from not dissimilar sources, under different but comparable conditions. Where conditions were eminently favourable for the formation of coal, they apparently were not so for petroleum, since beds bearing thick seams of coal are apt to contain little or no petroleum; on the other hand, where conditions did not permit of more than thin layers and local patches of lignite or coal being formed, larger quantities of oil are liable to be found one is tempted to say "instead of coal".'

The following analyses of upper Assam coals of Tertiary age will give a tolerably clear idea of their character.

The mean of two assays of Makum coal made in 1922 in the laboratory of the Geological Survey of India was as follows:—

Fixed carbon	53·2 per cent.
Volatile matter	44·0 ,, ,,
Moisture	1·2 ,, ,,
Ash	1·6 ,, ,,

Makum coal is largely used by the railways in Assam, by the river steamers navigating the Brahmaputra river and by a large number of tea gardens in the province. Considerable quantities are also often exported to Bengal.

The average composition given by three samples from the Upper Ledo colliery representing an aggregate thickness of 49 feet, and by

[1] *Mem. Geol. Surv. Ind.*, XL, Pt. I, p. 237 (1912).

five samples from the Tikak colliery representing an aggregate thickness of 47 feet, is shown below: –

	Upper Ledo.	Tikak.
	Per cent.	Per cent.
Fixed carbon	55·59	58·99
Volatile hydrocarbons	40·15	37·25
Moisture	1·80	2·09
Ash	2·46	1·67
TOTAL	100·00	100·00

Assays of Coal from the Jaipur and Nazira coal-fields.

—	Fixed carbon.	Volatile matter.	Moisture.	Ash.
	Per cent.	Per cent.	Per cent.	Per cent.
Jaipur field—				
Highest	53·71	45·10	10·31	18·18
Lowest	41·38	35·49	3·95	1·10
Average of 25 assays	48·78	39·80	6·12	4·82
Nazira field—				
Highest	54·64	42·90	7·23	14·45
Lowest	45·49	34·36	3·89	2·22
Average of 12 assays	50·04	38·11	5·49	6·36

Coal of excellent quality also occurs in the Namchik valley, a tributary on the left bank of the Dihing river, three days' journey above Margherita. The locality, which although only 18 miles in a straight line from Ledo, is difficult of access, was examined by Sir Edwin Pascoe in 1911. Five groups of seams were noticed, with a total thickness of about 60 feet of coal.

TABLE 26.—*Production of Tertiary coal during the years 1919 to 1928.*

—	1919		1920		1921		1922		1923	
	Tons.	*Per cent. of Indian total.*	Tons.	*Per cent. of Indian total.*	Tons.	*Per cent. of Indian total.*	Tons.	*Per cent. of Indian total.*	Tons.	*Per cent. of Indian total.*
Assam—										
Khasi and Jaintia hills .	600	*1·29*	570	*1·51*	443	*1·62*	453	*1·83*	200	*1·65*
Makum . . .	259,652		285,974		269,108		291,747		270,343	
Naga hills . . .	29,941		38,991		42,824		55,903		55,606	
Sibsagar . . .	1,541		..		..		..		..	
Baluchistan—										
Khost	23,703	*0·15*	22,535	*0·19*	31,253	*0·28*	33,866	*0·31*	26,504	*0·22*
Sor Range, Kalat, Mach.	10,625		11,406		23,374		26,269		16,058	
Burma—										
Kamapying (Mergui) .	..	..	..	..	..	..	..	..	163	..
Southern Shan States .	..	..	..	..	..	..	..	..	..	..
Kale (Upper Chindwin) .	..	..	..	..	..	..	..	..	213	..
Namma (Northern Shan States).	1,500	*0·01*	..	..	..	..	..	..	..	..
North-West Frontier Province—										
Hazara	20	..	..	..	..	..	..	..	..	..
Punjab—										
Jhelum (Dandot) .	35,845	*0·21*	47,803	*0·32*	50,639	*0·35*	47,832	*0·35*	43.253	*0·32*
Mianwali . . .	5,822		6,835		11,852		14,301		11,965	
Shahpur . . .	5,226		3,440		4,751		5,047		8,283	
Rajputana—										
Bikaner . . .	14,760	*0·06*	18,216	*0·10*	24,521	*0·13*	15,055	*0·08*	7,119	*0·04*
TOTAL (Tertiary Beds) .	**389,235**	*1·72*	**435,770**	*2·42*	**458,855**	*2·38*	**490,473**	*2·57*	**439,707**	*2·23*

TABLE 26.—*Production of Tertiary coal during the years 1919 to 1928*—contd.

—	1924		1925		1926		1927		1928	
	Tons.	*Per cent. of Indian total.*	Tons.	*Per cent. of Indian total.*	Tons.	*Per cent. of Indian total.*	Tons.	*Per cent. of Indian total.*	Tons.	*Per cent. of Indian total.*
***Assam*—**										
Khasi and Jaintia hills	280	*1·58*	845	*1·52*	555	*1·43*	825	*1·46*	588	*1·32*
Makum	274,479		262,959		255,189		271,220		238,926	
Naga hills	60,083		55,038		45,317		51.297		58,575	
Sibsagar	..		..		..		..		..	
***Baluchistan*—**										
Khost	25,678	*0·19*	17,085	*0·17*	3,545	*0·07*	1,734	*0·07*	2,542	*0·08*
Sor Range, Kalat, Mach.	14,879		17,712		12,041		12,710		15,389	
***Burma*—**										
Kamapying (Mergui)	255	*0·00*	..	..	..	..	..	..	..	..
Southern Shan States	..	..	25	*0·00*	..	..	..	..	..	..
Kale (Upper Chindwin)	..	..	..	..	..	..	..	..	..	..
Namma (Northern Shan States).	..	..	..	..	..	..	..	..	..	..
***North-West Frontier Province*—**										
Hazara	..	..	..	..	..	..	..	..	..	..
***Punjab*—**										
Jhelum (Dandot)	52,942	*0·38*	49,369	*0·36*	46,961	*0·33*	39,545	*0·28*	24,674	*0·21*
Mianwali	18,787		18,341		15,644		15,488		18,161	
Shahpur	8,693		6,952		5,438		7,671		3,317	
***Rajputana*—**										
Bikaner	21,870	*0·10*	28,153	*0·13*	31,275	*0·15*	17,358	*0·08*	27,386	*0·12*
TOTAL (Tertiary Beds)	**477,946**	*2·25*	**456,479**	*2·18*	**415,965**	*1·98*	**417,848**	*1·89*	**389,558**	*1·73*

Further proximate analyses of these Tertiary coals are given below :—

Tertiary Coals.

—	Moisture.	Volatile matter.	Fixed carbon.	Ash.
Assam (Miocene).	Per cent.	Per cent.	Per cent.	Per cent.
Borjan (resinous)	3·6	55·78	39·3	1·32 C.
Borjan (brights)	4·35	48·00	45·7	1·95 C.
Wakching	8·15	38·48	52·98	0·39
Namdang	2·04	42·27	54·48	1·21 C.
Rajputana (Lr. Eocene)				
Palana resin	0·65	99·09	0·06	0·2
Light lignite	5·13	71·45	11·57	11·85 C.
Dark lignite	12·55	46·67	36·38	4·40
Wet lignite	45·6	25·13	24·92	4·35
Dry lignite	8·5	41·8	40·8	9·5
Baluchistan (Lr. Eocene)				
Mach	10·71	41·43	45·68	2·18 C.
Mach	10·9	33·1	41·0	15·0
Digari	7·7	43·3	44·7	4·3
Khost	2·29	41·51	46·52	9·68 C.
Sharig	6·8	40·8	47·6	4·8
Salt Range, Punjab (Lr. Eocene).				
Dandot	5·87	43·65	38·04	12·44 C.
Dandot	6·13	36·81	47·17	9·89
Barochi	10·87	38·71	42·81	5·04
Makerwal	2·40	43·54	41·38	12·68 C.
Jammu, Kashmir (Lr. Eocene).				
Kalakot—7-foot seam, lower measures.	0·63	12·45	78·12	9·0 C.
Kalakot—16-foot seam, upper measures.	4·62	14·54	69·44	11·4
Sair—upper seam, upper measures.	8·43	20·93	60·16	10·48
Sair—upper seam, upper measures.	8·04	25·00	60·54	6·42

C Strongly coking coals.

N.B.—All the above analyses are of picked specimens and not samples. These analyses have been compiled from various sources. Many were made in the Geol. Surv. Lab., Calcutta, by Mahadeo Ram.

Less important from an economical point of view, but of considerable interest otherwise, are the seams of coal and lenticles of coaly matter in rocks other than those already mentioned. Workable coal-seams occur in other marine strata in Assam. The beds in the Garo hills, from fossil evidence, are of Cretaceous age. There are Eocene coals at Cherrapunji. Plant remains and thin lenticles of coal also occur in the marine Lower Cretaceous (Umia) beds in Kachh (Cutch). The Upper Gondwana (Lameta) coal in the Nerbada valley, near Jabalpur, occurs in fresh water deposits of Lower Cretaceous age. It is probable that certain other, thin, Upper Gondwana coals, in the same general region (Satpura highlands), may be older - probably of Jurassic (Oolitic) age. True Jurassic coals and carbonaceous beds with plant remains occur in the Southern Shan States (Burma) and the Punjab Salt Range. These occurrences fill in the gaps between the Tertiary coals and the Permian (Gondwana) coals of India. Definitely Lower Palæozoic coal, in rare lenticles, has been found in the black shales of the Vindhyan system in the Son valley near Rhotasgarh. These Bijaigarh shales have been correlated with the Suket shales of Rajputana in which, near Neemuch, fossils with Lower Cambrian faunistic affinities, were found several years ago by Mr. H. C. Jones. It is thought that the Vindhyan strata were deposited in the sea and it has been suggested that the Neemuch fossils may possibly be plant remains. Carbonaceous shales, which have repeatedly been mistaken for coal, also occur, in a lower horizon, in the Semri series below the true Vindhyan strata, but no actual coal has been found in these pre-Cambrian unfossiliferous rocks.

III Industrial Considerations.

The statistics of the export trade (beginning seriously from 1900) up to 1914 averaged less than a million tons. The highest pre-War figure was a little over a million tons in 1906. During the War these exports fell, due to shortage of shipping. In 1918 the exports were less than 75,000 tons, but rose rapidly to over 1,200,000 tons in 1920, when export restrictions were imposed to relieve the strain on the railways. A rationing scheme was drawn up and, at the time, had the entire approval of the commercial community. Later, however, the working of the scheme gave rise to doubts and the difficulties of the situation were enhanced by poor raising in

Export trade.

the coal-fields—4·5 million tons less in 1920 than the output of 1919. In April, 1922 all restrictions were removed on the export of cargo or bunker coal by sea to customs ports in India. The embargo was entirely removed from January 1st, 1923.

The effect of the embargo was the temporary disappearance of Indian coal from overseas markets, and the present quinquennial period, 1924-28, opened with practically no export trade to Penang, Singapore, Colombo, Sabang and Aden. It must be mentioned that none of these ports import any large quantities of coal for industrial purposes; also, in most of these markets Indian coal had not earned a reputation for good quality- due to carelessness in grading. Japanese coal and coal from Sumatra and South Africa, although known to be of no better quality than good Indian coal, were in considerable demand. Under these circumstances an Indian Coal Committee was set up.

Indian Coal Committee, 1925.

This committee was appointed by the Governor General in Council, under the Department of Commerce, Resolution No. 47-T. (5) dated the 20th September, 1924, and they issued their report on the 28th March, 1925. The committee were to enquire and report

'(1) generally what measures can be taken by Government, by the coal trade, by the railways and by the ports, whether singly or in combination, to stimulate the export of suitable coal from Calcutta to Indian and foreign ports; and

(2) in particular, whether effective measures can be taken for pooling and grading of Indian coal for export and for bunkering, and how the cost of such measures should be met.'

The Indian Coal Committee (1925) made a full investigation into the whole subject of the export trade and after discussing (1) the comparative merits and prices of Indian and other coals; (2) the possibility of economics in the coal-fields; (3) the transport of coal by rail; (4) railway freights, terminals and rebates; (5) assistance by and co-operation between collieries and railways; (6) the working of the Calcutta docks and coal depots; (7) steamer freights; (8) the establishment of a grading board, and (9) the impracticability of pooling in India, they concluded as follows:—' The railways and Port Commissioners can render most valuable assistance by reducing their charges, by speeding up transport and by facilitating the loading of coal in proper condition, but the main effort must come from the "coal trade itself" ....'

One of the important recommendations of the Indian Coal Committee (1925) was that a grading board should be appointed, whose duties would be to grade the various seams and arrange for the issue of certificates for each consignment of coal exported. The general outline was given for classifying all Indian coals, and it was suggested that a grading list should be published by the grading board as soon as possible classifying the different collieries and seams on this system. Only those collieries included in the grading list would be eligible for the special concessions from the Railways and from the Calcutta Port Commissioners, and only certified coal from those collieries would be given the above concessions. Act No. XXXI of 1925 was passed by the Indian Legislature and received the assent of the Governor General on the 23rd September, 1925.

Grading Board.

For the information of overseas buyers, the following particulars regarding the Indian coal-fields and the procedure adopted in granting 'grade' and 'shipment' certificates will be of interest :- The only coal-fields at present of importance to overseas buyers are those usually designated as the 'Bengal or Damuda Valley Coal-fields,' which include the collieries in Bengal and Bihar and Orissa. The whole of the coal raised in Bengal comes from the Raniganj coal-field, 130 miles west-north-west of Calcutta. The Jharia coal-field, another 30 miles in the same direction, lies wholly in Bihar and supplies 75 per cent. of the coal from the province of Bihar and Orissa. The above two coal-fields produce 75 per cent. of the total Indian output of coal and all the coal exported at present comes from these two fields. The most important seams in the Raniganj field are the Dishargarh, Poniati, Sanctoria, also the Ghusick, Koithi, Chanch, Salanpur A, Samla, Kajora and Jambad. In the Jharia field the best known seams of good quality are Nos. XIII, XIV, XIV-A., XV, XVII and XVIII. Seams X, XI, XII also contain good coal.

The grades fixed by the Board are as follows :—

Low Volatile.	*High Volatile.*
Selected grade.—Up to 13 % ash and over 7,000 calories or 12,600 B.T.U's.	Up to 11% ash ; over 6,800 calories or 12,240 B. T. U's and under 6% moisture.
Grade No. 1.—Up to 15 % ash and over 6,500 calories or 11,700 B. T. U's.	Up to 13% ash ; over 6,300 calories or 11,340 B. T. U's and under 9% moisture.
Grade No. 2.—Up to 18 % ash and over 6,000 calories or 10,800 B. T. U's.	Up to 16% ash, over 6,000 calories or 10,800 B. T. U's and under 10% moisture.
Grade No. 3.— All coals inferior to above.	

The office of the Coal Grading Board is in the Secretariat Buildings, 1, Council House Street, Calcutta.

TABLE 27.—*The approximate quantity of coal despatched to various ports during 1928.*

—	No. of Consignments.	Quantity Tons.
Akyab	4	9,305
Akyab and Rangoon	1	4,510
Bhavnagore	8	25,064
Bombay	47	288,461
Bombay and Colombo	1	5,750
Cannanore and Marmagao	1	4,661
Chittagong	5	20,451
Colombo	55	362,940
Colombo and Tuticorin	1	5,912
Cuddalore	7	53,850
Cuddalore and Madras	2	14,737
Feroke	4	30,260
Hongkong	20	120,874
Hongkong and Wahampa	1	7,096
Karachi	25	123,601
Madras	40	273,706
Mandapam	5	15,311
Manila	11	72,129
Marmagao	7	48,654
Mauritius	1	590
Moulmein	2	1,234
Penang	5	14,949
Penang and Port Sweetenham	1	5,074
Penang and Singapore	2	7,464
Porbunder	1	3,000
Port Blair	6	2,280
Port Okha	2	5,909
Rangoon	120	642,388
Singapore	5	39,567
Tuticorin	5	37,177
United Kingdom	4	150
Verawal	5	29,201
Yokohama	1	33
TOTAL	405	2,306,788

In the previous year (1927) there were 490 shipments, with a total of 2,381,726 tons, the record export figure for Indian coal. In that year Rangoon took 780,211 tons, Bombay 329,294 tons, Colombo 321,694 tons, Madras, 287,469 tons, Karachi 198,463 tons, Singapore 80,241 tons, Manila 57,701 tons, etc. The above table (27) and the figures just quoted show that most of the exports are coastwise to Indian ports. The penetration of Indian coal to Hongkong is a very pleasing testimony to the value of the grading board.

In the 'Publication of the Indian Coal Grading Board, 1928 containing a list of Graded Coals, Copies of the Act and rules, etc.,

(1929)' the following note deserves attention: 'Chemists have no uniform system of making analyses, and as discrepancy between calorific value air dried and oven dried is very high in "high moisture" coals, the Grading Board publish the following Note on the method adopted at the Government Test House, Calcutta, in the hope that its publication will lessen the liability to disputes between the Buyer and the Seller:—

'About 5 grams of the powdered sample are dried separately in an Air Oven at 105° to 110°C to constant weight. About 1 gram of the oven dried material is put in the screw press and compressed into a pellet. This pellet is then weighed and the calorific value is determined immediately afterwards by tests in a Mahler-Cook Bomb Calorimeter.'

Soft coke.

Although the present production of soft coke in India does not exceed 700,000 tons annually and is almost entirely used in the larger towns of Bengal and Bihar, there are attractive features in this trade. The production of soft coke during the years 1921 1928 is shown in Table 28. Soft coke manufacture has been described in 'Capital' (July. 5th and 12th, 1928). It is there shown that only the relatively inferior grades of coal are used for this purpose and that probably 100 tons of raw coal produce 50 tons of soft coke. When it is realized that the population of India is of the order of 300 millions and that barely 2 million tons of coal (raw coal and soft coke) are used as domestic fuel it is apparent that there are possibilities of great expansion in the household coal trade. With a view to assist this branch of the coal industry, the following Act of the Indian Legislature received the assent of the Governor General on the 1st October, 1929:—

Act No. VIII of 1929.—*An Act to provide for the levy of a cess on soft coke despatched by rail from collieries in the provinces of Bengal and Bihar and Orissa.*

1. (1) This Act may be called the Indian Soft Coke Cess Act, 1929...............
2. (*c*) "Soft-coke" means all coke which is unsuitable for metallurgical purposes.
3. (1) There shall be levied and collected on all soft coke despatched by rail from collieries in the provinces of Bengal and Bihar and Orissa a cess at the rate of two annas per ton.

5. The proceeds of the cess and any other monies received by the Committee shall be applied to meeting the expenses of the Committee and the cost of such measures as it may consider advisable to take for promoting the sale and improving the methods of manufacture of soft coke.

TABLE 28.—*Production of soft coke, in tons (of 2,240 lb.) during the years 1921—1928.*

Field.		1921	1922	1923	1924	1925	1926	1927	1928
Assam—									
Lakhimpur . .	Soft coke	*nil*	*nil*	*nil*	*nil*	*nil*	..	..	..
	Hard coke	256	332	[illegible]	683	802	876	1,010	1,027
	Coal used	768	995	1,226	2,048	2,405	..	..	..
Bengal—									
Raniganj	Soft coke	6,967	4,699	8,005	7,521	7,471	7,941	11,596	18,736
	Hard coke	1,356	809	747	540	350	760	918	714
	Coal used	14,410	9,809	14,509	13,437	12,044	..	..	..
Bihar and Orissa—									
Sontal Parganas . .	Soft coke	..	..	..	..	164	515	..	..
	Hard coke	..	..	..	..	*nil*	..	..	..
	Coal used	..	..	..	..	245	..	..	..
Raniganj	Soft coke	67,770	81,263	93,374	115,442	118,173	104,704	92,633	60,186
	Hard coke	*nil*	86	81	62	30	..	..	..
	Coal used	103,277	122,803	144,105	178,985	165,176	..	..	..
Jharia	Soft coke	71,730	98,859	113,464	176,797	290,807	397,589	500,812	606,520
	Hard coke	79,345	89,542	40,720	22,631	21,006	27,739	39,576	51,587
	Coal used	260,508	290,723	232,836	309,009	479,909	..	..	..
Bokaro	Soft coke	4,814	4,017	4,842	4,882	4,328	4,916	3,571	3,560
	Hard coke	219	*nil*	*nil*	285	302	253	941	3,205
	Coal used	7,709	5,042	7,315	7,941	7,069	..	..	..
Giridih	Soft coke	*nil*	*nil*	*nil*	*nil*	26	..	..	..
	Hard coke	39,961	42,752	40,884	37,123	32,722	..	..	..
	Coal used	53,758	49,637	50,926	48,951	44,113	..	..	..
Central Provinces—									
Pench Valley . .	Soft coke	..	15	..	100	..	..	..	..
	Hard coke	..	*nil*	..	*nil*	..	..	..	..
	Coal used	..	21	..	150	..	..	..	..

These figures do not include metallurgical coke made at the various iron works.

Coking coal.

The most important reserves of coking coal are shown in the following table:—

Quality.	Field and seams.	Amount in millions of tons (approx.)	Remarks.
I. Highest grade metallurgical coke.	*Giridih.* Lower Karharbari .	9	Specially low in phosphorus and ash. Suitable for making iron of Bessemer quality or ferro of standard grade.
	TOTAL .	9	
II. Good metallurgical coke.	*Jharia.* 13, 14A, 14, 15 and 17.	732	Good quality coal. Total estimated 1,100 million tons. Allowance 33⅓%. Best coke from coal slack.
Ditto .	*Giridih.* Lower Karharbari .	30	Excellent coke physically; sometimes rather high in ash, particularly if made from coal slack.
Ditto .	*Raniganj* Victoria-Laikdih and Ramnagar.	50	This coke has been utilised in the Kulti furnaces. All allowances made; 25 million tons each.
	TOTAL .	812	
III. Fair metallurgical coke.	*Jharia.* 10, 11, 12, 16 and 18.	800	Some of this coal is as good as Class II. Total estimated 1,200 million tons Allowance 33⅓%.
Ditto .	*Raniganj.* Dishergarh . .	48	Best used by carefully mixing with 17 seam or others by experiments. All allowances made.
	Sanctoria . .	36	
	Begunia . .	25	
Ditto .	*Bokaro.* Kargali . .	365	Some of this is known to be of good quality Class II coal, but there is a little uncertainty about the ash in the remainder. All allowances made.
	TOTAL .	1,274	
IV. Good coking coal, but not of metallurgical quality.	*Assam fields.*	600	Very high in sulphur. If this impurity can be removed, this coal could be included in Class I or Class II.
	TOTAL .	600	

It is, of course, known to be the custom in iron works to make coke from a blend of at least three and sometimes six or seven coals. The Indian Iron and Steel Co. use coking coals from the following Jharia seams:—

No. of seam.	Colliery.
13, 14 and 15	Gaslitan
12, 13, 14 and 15	Union.
12, 13, 14 and 15	Sondra. Standard. Khas Jharia. Bhulanbararee.
11	National.
11 and 12	Khas Angarpathra.

The analysis of the coals (when mixed together) is:—

	Per cent.
Moisture	1·98
Volatile matter	25·74
Fixed carbon	62·20
Ash	11·58
Sulphur	0·50
Phosphorus	0·10

while a complete analysis of the coke produced is:—

	Per cent.
Moisture	2·58
Volatile matter	1·32
Fixed carbon	76·45
Ash	19·37
Details of ash—	
Silica	9·40
Alumina	5·59
Ferric oxide	2·44
Lime	0·89
Magnesia	0·12
Phosphoric oxide	0·41
Sulphur	0·52
	19·37

During the past five years attention has been directed to the subject of the coal reserves of India. Although no computation of the total reserves has been published in recent years, it is known that this country possesses great resources of coal. It is true that much of this coal is rather high in ash and that some, particularly the Tertiary coals, have a high sulphur content. Although for some purposes these factors are unattrac-

Coal reserves.

tive they do not render the coals entirely unfit for use. As a result of enquiries following the investigations of the Indian Tariff Board in regard to the Indian steel industry it was found that the greater part of the reserves of coal suitable for the manufacture of metallurgical coke was confined to the Jharia coal-field.

Reserves of coal of all kinds in India (in million 2,240 lb. tons).

Coal-fields.	Total all kinds of coal.	Total coals of coking quality.*	All coals other than coking coals.*
Giridih	60	10	20
Raniganj	22,000	408	21,592
Jharia	20,500	2,300	18,200
Bokaro Ramgarh . . .	1,000	600	400 (at least)
Karanpura S. . . .	75	Not fully tested	8,975
Karanpura N. . . .	8,900		
Aurunga	20	....	20
Hutar	9	Said to be some	9
Daltonganj	9	....	9
Korea, Rewa	200	....	200
Sirguja Korba, Sambalpur .	200	Some in Korba small quantity.	..
Talchir	44	....	44
Wardha and Godavari Valleys	400	....	400 150
Satpura Region . . .	150	Some, very small amount.	..
Assam	600	600	There are some.
Rajmahal area . . .	200	Not properly tested	200
Other fields	100		100
TOTAL .	54,467	3,948	50,519
Allowing ⅓ for losses . .	**36,311**	**2,632**	**33,679**

* Coal which might be suitable for the manufacture of metallurgical coke.

Losses and remedy.

In two valuable papers, (1) 'The Coal Resources of the Jharia Coal-field' and (2) 'Coal lost by Fires and Collapses in Indian Coal Mines' (*Rec. Geol. Surv. Ind*,, LXII Pt. 3, 1929), Mr. Norman Barraclough, Inspector of Mines, has disclosed a very serious state of affairs in the working of the coal mines of the Damuda valley. He says in his final paragraph (p. 388, *supra*): 'If proper precautions had been taken the loss of coal by fires and collapses in the Raniganj and Jharia coal-fields would probably not have been more than one-tenth of what it has actually been.' In connection with such a statement it must be recorded that almost all competent colliery managers and mining engineers are of the opinion that the only remedy against the present losses (one ton lost for every ton mined) is that of some system of stowing the voids or 'goaves' in collieries with sand. With the price of coal as low as it is the cost of sand-packing or hydraulic stowing militates against its adoption. The whole subject of coal economy was threshed out by the committee appointed in 1920 to consider a special report by Mr. Treharne Rees. It has been found that in giving practical effect to their recommendations the difficulties encountered would be almost insurmountable; no satisfactory measures have yet been devised. The principal recommendations of the majority report of the Coal Committee are as follows:—

(1) 'That no improvement in the present wasteful methods can be expected without State interference, that such interference should take the form of a Controlling Authority with legal powers designed to ensure conservation and economic extraction, and that such authority should consist of a new Government Department and a Board sitting in Calcutta.'

(2) 'That a steady and sufficient supply of wagons, with the requisite facilities for moving them is the most urgent need of the industry.'

(3) 'That sand-stowing should be made compulsory within certain limits and with provisions for compensation, and that funds for the purpose should be raised by a cess and a duty of eight annas a ton on all coke and coal; that the cess should be imposed as soon as possible, be collected by the railway companies on despatches, and be administered by the controlling authority; that a Government officer be deputed to ascertain the amount

of sand available and that one or more railway officers be placed on special duty to enquire into the question of transport and distribution of sand.'

(4) 'That the Land Acquisition Act be amended to provide facilities for the acquisition of:—

(*a*) surface rights for colliery purposes,

(*b*) sand and other materials suitable for stowing, and

(*c*) land required for the conveyance of sand.'

(5) 'That labour recruitment, electrical development, briquetting and coal-washing should be left to private enterprise.'

(6) 'That the time is not ripe for compulsory weighment, statutory shifts, and restrictions on methods of coking.'

Labour.

In the accompanying Tables, 29, 30, 31 and 32, are shown: (29) the number of persons employed in the Indian Coal-mining Industry during the period 1919 to 1928; (30) the comparison of death rate from accidents at coal mines in British India with those in Indian States during the years 1919 to 1928; (31) the production of coal compared with deaths from coal-mining accidents in India during the years 1919 to 1928; and (32), for comparison, the death rate from coal-mining accidents in Great Britain.

Although the efficiency of the Indian coal miner is relatively low compared with that of the collier in most countries, yet the cost of getting the coal is also low. The question of increasing the efficiency by the introduction of machine mining has received careful consideration from most of the larger colliery companies, and there seems to be little doubt that with increased demands for coal such modern methods of coal cutting will be employed to a greater extent than is now possible.

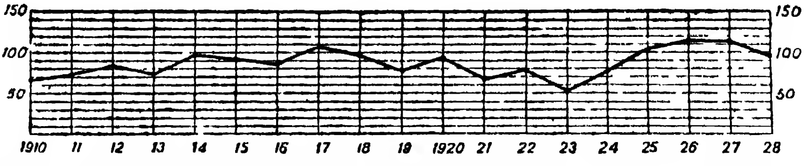

Fig. 9. Production of coal in thousands of tons per life lost by coal mining accidents.

Coal-dust.

The protection of mines from the dangers of coal-dust has been carefully investigated by a special committee appointed by the Government of India 1923 (Department of Industries and Labour, Resolution No. M-498,

TABLE 29.—*Number of persons employed in the Indian Coal-Mining Industry during the years 1919 to 1928.*

Province.	1919	1920	1921	1922	1923	*Average.*	Per cent. of average total.	1924	1925	1926	1927	1928	*Average.*	Per cent. of average total.
Assam . . .	3,230	3,171	3,389	3,636	3,901	*3,465*	1·73	4,464	4,199	4,523	4,034	4,216	*4,287*	2·28
Baluchistan . .	1,006	986	1,330	1,492	1,195	*1,202*	0·60	1,108	951	232	323	254	*574*	0·30
Bengal . . .	48,642	43,782	45,813	44,893	44,251	*45,476*	22·70	43,621	42,781	43,498	44,274	43,855	*43,606*	23·21
Bihar and Orissa .	129,927	118,260	126,431	119,790	123,554	*123,592*	61·69	128,523	114,934	112,945	109,196	108,546	*114,829*	61·11
Burma . . .	70	242	270	65	157	*161*	0·08	23	19	..	..	..	*8*	..
Central India . .	1,293	1,617	1,967	2,595	2,762	*2,047*	1·02	3,157	2,759	2,497	3,259	3,144	*2,963*	1·58
Central Provinces .	6,306	8,403	12,152	13,255	9,857	*9,995*	4·99	8,125	9,174	8,366	6,553	6,923	*7,828*	4·17
Hyderabad . .	11,974	12,446	12,502	13,402	13,558	*12,776*	6·38	13,590	12,701	12,134	11,464	11,816	*12,341*	6.57
N.-W. F. Province .	5	..	..	..	..	*1*	..	..	..	..	..	..	..	..
Punjab . . .	1,191	1,320	1,898	1,686	1,544	*1,523*	0·76	1,575	1,579	1,388	1,260	766	*1,314*	0·70
Rajputana . .	108	115	127	99	99	*110*	0 05	120	165	166	169	167	*157*	0·08
TOTAL .	203,752	190,342	2 5,879	200,913	200,878	*200,353*	100·00	204,3[illegible]	189,262	185,749	180,532	179,68[illegible]	*187,907*	10[illegible]·00

TABLE 30.—*Comparison of death-rate from accidents at coal mines in British India with those in Indian States during 1919 to 1928.*

YEAR.	AVERAGE NUMBER OF PERSONS EMPLOYED DAILY.		DEATHS FROM ACCIDENTS.		DEATH-RATE PER 1,000 PERSONS EMPLOYED.	
	British India.	*Indian States.*	British India.	*Indian States.*	British India.	*Indian States.*
1919 . .	190,377	*13,375*	260	*27*	1·37	*2·02*
1920 . .	176,164	*14,178*	172	*17*	0·98	*1·18*
1921 . .	191,283	*14,596*	257	*29*	1·34	*1·99*
1922 . .	184,817	*16,096*	209	*31*	1·13	*2·11*
1923 . .	184,459	*16,419*	332	*31*	1·80	*1·89*
Average .	*185,420*	*14,933*	*246*	*28*	*1·32*	*1·84*
1924 . .	187,439	*16,867*	230	*41*	1·23	*2·61*
1925 . .	173,637	*15,625*	186	*16*	1·07	*1·02*
1926 . .	170,952	*14,797*	171	*13*	1·00	*0·88*
1927 . .	165,640	*14,892*	181	*15*	1·09	*1·01*
1928 . .	164,560	*15,127*	218	*16*	1·32	*1·06*
Average .	*172,446*	*15,461*	*197*	*21*	*1·14*	*1·31*

TABLE 31.—*Production of coal compared with deaths from coal-mining accidents in India.*

—	1919	1920	1921	1922	1923	*Average.*	1924	1925	1926	1927	1928	*Average.*
Deaths from coal-mining accidents.	287	189	286	243	363	*274*	274	202	184	196	234	*218*
Thousands of tons of coal raised for each life lost.	79	95	67	78	54	*75*	77	103	114	113	96	*101*
Lives lost per million tons of coal raised.	12·7	10·5	14·8	12 8	18·5	*13·9*	13·0	9·6	8·8	8·9	10·4	*10·1*
Death-rate per thousand persons employed.	1·41	0·99	1·39	1·21	1·81	*1·36*	1·34	1·07	0·99	1·09	1·30	*1·16*

TABLE 32.—*Death-rate from coal-mining accidents in the United Kingdom.*

—	1919	1920	1921	1922 (*a*)	1923 (*a*)	1924	1925	1926 (*a*)	1927
Number of persons employed.	1,191,313	1,248,224	1,144,311	1,162,754	1,220,431	1,230,248	1,117,828	1,041,632	1,037,391
Number of deaths .	1,118	1,103	756	1,105	1,297	1,201	1,136	649	1,128
Death-rate per 1,000 persons employed.	0·94	0·88	0·66	0·95	1 06	0·98	1·02	(*b*) 0·62	1·09
Deaths per 1,000,000 tons of coal raised.	4·67	4·60	4·49	4·32	4·57	4·36	4·53	4·95	4·36

(*a*) In this year, work at coal mines was reduced by protracted disputes and the number of deaths from accidents were correspondingly affected.

(*b*) This figure would perhaps be more correctly estimated as 1·08.

dated 24th July, 1923). This committee have now submitted their second report (1929). They state that—

(1) 'The dust of any coal seam of commercial value in India, if in a sufficiently fine state of division and in sufficient quantity, is capable of rendering an atmosphere of ordinary air explosive......'

(2) 'The dust from a seam having a large percentage of ash and a low percentage of volatile matter is less readily ignitable than dust from a seam low in ash and high in volatiles......'

(3) '......A correctly proportioned, properly placed and properly tamped charge of any explosive is unlikely to ignite coal-dust......'

(4) 'The removal of all fine coal-dust within a comparatively small radius of a charge of explosive before the shot is fired will practically eliminate the risk of an explosion.'

(5) 'It is extremely improbable that an explosion of coal-dust will arise from a charge of permitted explosive which has passed the prescribed tests in Great Britain and which is used in compliance with the conditions attached to its use.'

It will be remembered that the Indian Mines Act, 1923, received the assent of the Governor General on the 23rd February, 1923, and the Government of India took advantage of its enactment to revise the regulations relating to the safety of mines and persons engaged in mining. The new regulations came into force on the 1st July, 1924. Since then 'The Indian Coal Mines Regulations,' 1926, made under Section 29 of the Indian Mines Act, 1923, has been published in Notification No. M-1055 (1), dated 7th September, 1926, of the Government of India, in the Department of Industries and Labour, and amended in Notification No. M-1055 (1), dated 13th May, 1929. 'Regulations for prohibiting the employment of Women underground in Mines' has been published in Notification No. M-1055, dated 7th March, 1929, of the Government of India, in the Department of Industries and Labour.

Precise information relating to mining regulations, etc., has recently been published in a valuable handbook by Mr. R. R. Simpson, Chief Inspector of Mines in India. This volume—'The Indian Mines Manual' (1929) gives all the available information on recent

legislation in regard to mines, mining leases, land acquisition, Indian Electricity Rules, Indian Explosives Act, Workmen's Compensation Act (1923), Indian Boilers Act (1923), the Bengal Mining Settlements Act (1923) and the Bihar and Orissa Mining Settlements Act (1920).

Copper.

[E. H. PASCOE.]

Copper was formerly smelted in considerable quantities in Southern India, in Rajputana, and at various places along the outer Himalaya in which a persistent belt of killas-like rock is known to be copper-bearing in numerous places, as in Kulu, Garhwal, Nepal, Sikkim and Bhutan. In Chota Nagpur several attempts have been made to work lodes reputed to be rich in the metal. At Baraganda in the Giridih sub-division of Hazaribagh, a low-grade ore-body of about 14 feet in thickness was prospected by shafts to a depth of 330 feet, and an unsuccessful attempt was made many years ago to work the lode.

Singhbhum.

In the Singhbhum district of Bihar and Orissa a copper-bearing belt, marked out by old workings, persists for a distance of some 80 miles, stretching from Duarparam on the Bamini river in the Kera Estate, in an easterly direction through the Kharsawan and Saraikela states, into Dhalbhum, where the strike of the belt curves round to south-east, running through the Rajdoha and Matigara properties formerly belonging to the Cape Copper Company, to Bhairagora at the extreme south-eastern end.

The copper ores occur as rather indefinite lodes interbedded with the Dharwar phyllites and schists. Sometimes the ore is collected into fairly well-defined bands, but very frequently it occurs in the form of grains so sparsely disseminated through a considerable thickness of schists as to be unworkable. When concentrated into definite lodes, as at Matigara or Mosaboni, the ore may be of high grade, and well worth working when it can be proved to exist in sufficient quantity to render it worth while to erect the plant necessary to handle large quantities of ore.

These copper-ores have been the subject of exploitation on European lines by various companies during the past fifty years,

always until recently with disastrous results, in some cases due to the poor character of the deposit attacked, and in others to the unwise expenditure of a limited capital on expensive plant before the deposit had been proved. Such results caused business and mining men to avoid the Singhbhum copper and consequently, in the absence of private enterprise, the Geological Survey of India, during the years 1906 to 1908, carried out a series of diamond-drilling operations on the belt. This directed attention to the problem, and the Cape Copper Company, after a further prospecting campaign, took over the Rajdoha Mining Company's rights at Matigara. The property known as Rakha Hills Mines, was actively developed and, had it not been for the difficulty of procuring plant during the war, smelting furnaces would have been in operation before 1918.

Rakha Mines, Matigara.

At the end of August in 1918 the Company's ore reserves amounted to 407,000 short tons of an average assay value of 3·8 per cent. copper. An electric power house, a concentration plant and a blast furnace with sintering and converting plants had been erected, and a refinery was completed during the quinquennium 1919-23. The total production of copper-ore and metal from the Rakha mine during that five-year period amounted to 130,797 and 3,549·76 tons, respectively, valued at Rs. 18,08,141 and Rs. 41.58,154. In March, 1923 mining operations were stopped and the company's property was placed in the hands of receivers.

As seen at the outcrops the Singhbhum lodes seem to be very poor where they have not been removed by the ancients. Typically they consist of a small thickness of vein quartz, associated with malachite, chrysocolla, and red oxides of iron containing a small quantity of copper, possibly as red oxide, with sometimes small encrustations of liebethenite. In depth, as seen in the diamond drill cores and the levels of the Matigara mine, the ores consist practically entirely of chalcopyrite. The other minerals noticed above are evidently the outcrop alteration products of the yellow sulphide. Judging from small specimens found on the dump-heaps of the old workings there must be a zone of chalcocite not very many feet below the surface, probably formed by secondary enrichment at the expense of the portions of the deposits denuded away, and of those now appearing as gossans of oxide ores. The primary chalcopyrite ores have probably been deposited in their position as rather indefinite lodes following the bedding of the schists, after

the arrival of the latter in their present position. The schists with which the copper lodes are associated are chiefly varieties of muscovite and chlorite-quartz-schists, with quartzite layers. Apatite and tourmaline are also common minerals in them.

The information obtained in the borings put down by the Geological Survey is shown in Table 33. These results show that much of the ore of Singhbhum is of low grade, and just below what is likely to be payable except when working on very large quantities of ore. A thickness of 16·80 feet, averaging 2·65 per cent. of copper, found at Laukisra, shewed that the lode was worth further testing by private enterprise.

The characteristic and persistent band of chalcopyrite with quartz blebs intersected by the Matigara bore-hole at 306 feet, where it yielded 12·81 per cent. of copper, but was only 3 inches thick, and which was seen in the Matigara mine in the 228-foot level with a thickness ranging from 6 inches to 2 feet, was followed on the dip in the Gladstone Shaft and found to extend below the depth proved by boring.

TABLE 33.—*Results of diamond-drill boring on the Singhbhum copper lodes.*

No. of bore-hole.	Locality.	Total depth of hole.	Depth of lode or cupriferous zone.	Actual thickness of lode assayed.	Percentage of copper.
1	Kodomdiha . .	..	392′ 404′ .	8 feet . .	5·10
2	Do. . .	1,093′	1,069′ . .	1 foot . .	1·82
3	Galudih (Rogadih) .	430′	131′—294′ .	..	..
			293′ . .	13 inches . .	0·61
4	Landup (Nadup) .	165′	197′ 198′ .	14 inches . .	3·33
5	Matigara . .	837′	693′ 697′ .	3 feet 2 inches .	2·00
			697′ 701′ 8″ .	3 feet 8 inches .	1·29
			733′ 5″ -736′ 1″	2 feet 1 inch .	1·01
			736′ 1″—736′ 5″	3 inches . .	12·81
			736′ 5″—739′ .	2 feet . .	0·42
6	Laukisra . .	392′	150′--168′ .	16 feet 10 inches	2·65
			169′—171′ .	1 foot 10 inches .	2·13
			179′ -184′ .	4 feet 8 inches .	1·37

Mosaboni Mines; Bihar & Orissa.

The Cordoba Copper Company, under the management of Messrs. John Taylor and Sons, commenced prospecting operations in the Mosaboni area, Singhbhum, in June, 1920 and met with most promising results. After piercing a zone of secondary enrichment in which

the predominant ores were malachite and cuprite, an impoverished zone made its appearance in which there was practically no ore, although the lode channel was well defined. Beyond the impoverished zone chalcopyrite began to make its appearance in the shape of small lenses of ore. At a vertical depth of 169 feet from the surface, tunnels driven along the lode proved solid chalcopyrite, in some places 2 feet wide, over a considerable distance in length, giving values of from 10 to 25 per cent. of copper. Up to February, 1924 twelve shafts had been sunk on this lode. Below the 169-foot horizon some promising ore ground carrying solid chalcopyrite was opened up.

Another company, the North Anantapur Gold Mines, Limited, also managed by Messrs. John Taylor and Sons, commenced an investigation of the Sideshur-Kendadih copper area in Singhbhum in 1922. The area lies between the concessions of the Cape Copper Company and the Cordoba Copper Company. By the end of 1923 one shaft had reached 258 feet without intersecting the lode. The ore is a sulphide. This company also started exploiting copper in Kharsawan State, about eight miles N.W. of Amda railway station, Bengal-Nagpur Railway.

In 1924 the Cordoba Copper Co. was reconstructed as the Indian Coppe Corporation, Ltd., with a capital of £225,000, and acquired not only the properties of the Cordoba Copper Co., but also those of the North Anantapur Gold Mines, Ltd., lying immediately to the north, and a property in Kharsawan State prospected and owned by the Ooregaum Gold Mining Co. of India, Ltd.

Work was concentrated upon the Mosaboni area, and by the end of April, 1925 nearly 329,000 tons of 4·04 per-cent. ore had been developed. Operations were suspended during 1926 pending the raising of the capital required for the erection of the necessary concentrating, smelting, refinery and power plants. Early in 1927 the Anglo-Oriental and General Investment Trust, Ltd., London, assumed control, a sum of £350,000 was subscribed for the purpose and the erection of the plant was commenced at the company's new site at Maubhandar, Ghatsila. The surface and underground ore-reserves now total 755,630 short tons of 3·78 per cent. copper-ore, representing a copper content of 28,584 short tons. Two lodes have been developed in the Mosaboni mine, the Main and the Western, both of which have been opened up to a depth of 500 feet on the dip of the lode. There is every indication that the

lodes will persist to a further considerable depth. Stoping commenced on a small scale at the end of 1928, and 4,715 short tons of ore were broken. During most of 1928 development was confined to the blocking out of known ore-bodies in preparation for stoping and the completion of the main shaft for hoisting from certain levels. The old pumps have been replaced by electrically-driven centrifugal pumps, and the place of all the old steam-driven equipment has now been taken by :—two electrical compressors, each of a thousand cubic feet capacity; one electrical hoist (50 tons per hour); one electrically-driven primary crushing plant with a capacity of 50 tons per hour; one belt-conveyer delivering crushed ore to the ropeway bins; and one aerial ropeway, 5½ miles in length, delivering ore to the reduction works at Maubhandar.

The main shaft is now over 632 feet below the surface. The main items of the plant at Maubhandar are as follows:- railway siding; aerial-ropeway unloading station and ore bins; aerial-ropeway driving station and tension race; flotation mill for concentrating ore; bedding bins; reverberatory smelting furnace, converters and refinery furnace; power house (1,875 kilo-watt capacity); boiler house (3 water-tube boilers); pulverised coal plant; flux-crushing plant; water-pumping station; machine shop; and laboratory.[1] Table 34 gives the production of copper-ore and copper-matte during the quinquennium under consideration. The figures for Singhbhum up to and including 1927 are not of much significance, but the production of 18,055 tons in 1928 is an encouraging sign of what may be expected from this area.

Darjeeling area.

Copper-ore has been mined intermittently for many years by primitive native methods in the Darjeeling district.[2] The method of smelting has been described by Mr. F. R. Mallet (*Mem. Geol. Surv., Ind.*, Vol. XI, pp. 70-72). Indications of copper have been observed in over a dozen places of which eleven have been examined. The ore consists of copper pyrites, often associated with iron pyrites, and is usually of a low grade. It does not occur in true lodes but appears to be disseminated through the slates and schists of the Daling series. A seam said to be from 4 inches to a foot in width and to consist of solid ore, is exposed in the bed of the Chel river

[1] From information kindly supplied by the Indian Copper Corporation, Ltd.

[2] *Mem. Geol. Surv., Ind.*, XI, pp. 69-83; *Rec. Geol. Surv., Ind.*, XV, pp. 56-58; *Ibid.*, XXIII, pp. 257-258.

Table 34.—Production of Copper-ore and Copper-matte during the years 1924 to 1928.

—	1924		1925		1926		1927		1928	
	Quantity	*Value*	Quantity	*Value.*	Quantity	*Value*	Quantity.	*Value.*	Quantity.	*Value*
	Tons	*Rs.*	Tons	*Rs.*	Tons.	*Rs.*	Tons	*Rs.*	Tons.	*Rs.*
Bihar and Orissa—										
Singhbhum .	..	..	(*a*)26,319	(*b*) *5,26,380*	9,504	(*b*) *1,90,0[illegible]0*	5,000	(*b*) *1,00,000*	18,055	(*b*) *3,61,100*
Burma—										
Northern Shan States.	(*c*)2,935	*15,94,527*	(*c*)8,029	*34,88,5[illegible]2*	(*c*)11,441	*44,78,064*	(*c*)11,872	*44,13,206*	(*c*)10,978	*46,26,403*
Madras—										
Nellore . .	..	..	..	..	4	*160*	10	*400*	..	..
Mysore . .	.	..	..	.	.	.	.	..	5	(*b*)
TOTAL .	**2,935**	*15,94,527*	**34,348**	*40,14,932*	**20,949**	*46,68,304*	**16,882**	*45,13,605*	**29,038**	*49,87,503*
Total value in Sterling	.	*£114,714* (£1=Rs 13 9)	.	*£301,875* (£1=Rs 13 3)	.	*£348,[illegible]* (£1=Rs 13 4)		*£336,836* (£1=Rs. 13 4)	..	*£372,202* (£1=Rs 13 4)

(*a*) Combined production for 1924 and 1925, separate figures are not available
(*b*) Estimated at Rs 20 per ton
(*c*) Copper-matte

(26° 58′; 88° 46′). The mine two miles north-east of Kalimpong was abandoned on account of the hardness of the containing quartzite. At Komai (27° 1′; 88° 51′) on the left bank of the Mo Chu copper-ore is distributed in fairly large masses in bands from 2 to 4 feet in thickness occurring in slates [1]; a sample from a prospecting drift yielded on assay 3·5 per cent. of copper and 1 dwt. 8 grs. of gold per ton, while a picked sample gave 26 per cent. of copper. At Mangphu on the left bank of the Tista there is an old copper mine whose annual output is said to have reached 5,760 lbs. of metal; the ore, which is said to yield an average of about 4 per cent. of metal, occurs in lenticular layers up to a foot thick in a band of clay slate. Attempts to work the mine at Pashok between 1854 and 1870 were unsuccessful chiefly owing to the very low grade of this ore; the mine is now completely obliterated by a tea-garden. Near the head of the Chochi stream, 1,100 feet above and a mile north of Rani Hat, copper-ore has been worked on a comparatively extensive scale; the ore stratum averages about 18 inches in thickness, and has been proved to a distance of over 90 feet along the dip. A copper mine was opened some 43 years ago on the western slope of Youngri hill; the seam was, however, thin and the assay poor.

Sikkim.

Recent work has also proved the existence of lodes of possible value in Sikkim, where the copper is associated with bismuth, antimony, and tellurium, one of the minerals discovered being the rare mineral tetradymite, Bi_2Te_3. Another mineral identified by the late Mr. Blyth in the Geological Survey Laboratory is linnæite, a sulphide of cobalt, Co_3S_4.

Prospecting licenses and mining leases were secured by Messrs. Burn & Company, in the copper-bearing areas in Sikkim, and extensive prospecting operations were conducted for some years; they were suspended, however, during the War, and have not been resumed. The following notes are from a report made in October, 1908 by Mr. C. Wilkinson, showing the principal results obtained up to that date [2].

[1] *Rec. Geol. Surv. Ind.*, XXXI, pp. 1-4 (1904).

[2] Published with the kind consent, through the late Mr. A. Whyte, of Messrs. Burn & Co.

At Bhotang, 44 miles from Siliguri on the road to Gangtok, some old workings were examined and two parallel lodes of pyrrhotite were opened up and found to contain varying quantities of zinc blende, galena, and chalcopyrite. The lodes are disturbed but development work yielded results which were regarded as satisfactory.

At Kikchu, about 7 miles to the north of Gangtok and within a mile of the Gangtok-Lachen road, a distance of 75 miles from Siliguri, a more clearly defined copper lode was discovered. It was found, by opening up the outcrops for a length of 200 feet along the bed of the Sehchu, that the lode had an average width of 3 feet, bearing 6·14 per cent. of copper. By cutting the vein at a greater depth with an adit it was found that for 80 feet on an average width of 40 inches the lode contained an average content of 6·8 per cent. of copper.

In the Rhotak *colah*, a tributary of the Great Ranjit river, 13 miles by pack road from Darjeeling, there are extensive old workings which have been almost obliterated by landslips. Five samples of the lode, taken at irregular intervals along a length of 500 feet, gave an average of 5·6 per cent. of copper.

At Sirbong, about 1 mile north-east of the junction of the Rhotak and Khani *colahs*, a lode of pyrrhotite containing chalcopyrite was exposed, yielding, for an average thickness of 2 feet 6 inches, 6·45 per cent. of copper, the sampling being continued for about 100 feet along the outcrop.

The Pachikhani mine, which is reputed among the natives to be one of the richest of the mines in Sikkim, has been overwhelmed by a landslip, and has not yet been sufficiently opened for further examination (see Mr. Bose's remarks on this mine in *Records, Geological Survey of India*, Vol. XXIV, page 227).

Another deposit was found near Pachikhani on the road from Rungpo to Pakyong, about 7 miles from the former locality. It was found that the chalcopyrite, concentrated within a zone of mica-schist about 4 feet wide, yielded on an average 4 per cent. of copper.

Within 200 yards of the bridge crossing the Rungpo on the road from Rungpo to Rhenok, and about a mile to the north-east of the second of the two Pachikhani mines, there was found a quartzose vein following the foliation-planes of the Daling series and containing 3·97 per cent. of copper for an average thickness of 1 foot; it is considered that this ore could be readily concentrated by hand-picking.

In the neighbourhood of Pakyong in the Pachi *colah* valley, two veins were found cropping out at right angles to the stream and at a distance of 200 yards from each other. The average analysis of the samples collected from one of these lodes gave the following results:—

	Per cent.
Copper	3·30
Iron	11·23
Lead	10·10
Zinc	2·50
Sulphur	11·68
Silica	40·10

The other lode, consisting mainly of galena, varied in thickness from 6 inches to 2 feet, and contained an average of 21·12 per cent. of lead with 5·9 per cent. of zinc.

In 1911 the two most important of these deposits, namely, Bhotang and Dikchu, were examined by the Geological Survey of India.[1] As the result of this examination, development work was resumed at Bhotang with favourable results. Both deposits occur interbedded with the associated rocks, being of the nature of interbedded replacement deposits; but whereas the Bhotang deposit is in a comparatively unmetamorphosed form of the Daling series, the Dikchu deposit occurs in the belt of highly crystalline mica-schists with associated gneisses, forming a boundary zone between the Daling series and the Sikkim gneiss. In both cases, the copper-ore is chalcopyrite, the chief associated sulphide being pyrrhotite. But, especially at Bhotang, galena and blende are also of somewhat common occurrence. The origin and mode of occurrence of these ores appear to be similar to those of the Singhbhum copper lodes. In each area the bodies of copper-ore have been formed by the metasomatic replacement of the associated rocks; in each area also the copper-bearing formations are close to large masses of granitic rocks, from which, one may conjecture, the copper-bearing solutions were derived. In Singhbhum there are numerous basic (epidioritic) dykes associated with both the granites and the metamorphic rocks (schists, quartzites, etc.), and, as an alternative to the derivation of the copper-bearing solutions from the granites, it is possible to suppose them to be closely connected with the basic dykes.

[1] L. L. Fermor; *Rec. Geol. Surv. Ind.*, XLII, p. 75 (1912).

Although the deposits of Sikkim are similar in mode of origin to those of Singhbhum, they differ from them remarkably in the diversity of their mineral contents, which frequently include chalcopyrite, pyrite, pyrrhotite, blende, and galena; in Singhbhum, on the other hand, the copper-lodes show, as a rule, only two sulphide minerals, chalcopyrite and pyrite, with traces of chalcocite at higher levels, probably representing a zone of secondary enrichment. In both Sikkim and Singhbhum, azurite, malachite, chrysocolla, and chalcanthite are found in the oxidised zones of the lodes, but in Sikkim, where the slopes are very steep and denudation under the influence of a moist climate and heavy rainfall very rapid, the oxidised zones are much less prominent than in Singhbhum. In Sikkim the sulphide minerals may crop out at the surface in the fresh condition, but this practically never happens in Singhbhum, where one might doubt the existence of copper deposits, were it not for the presence of numerous ancient outcrop workings stained with green and blue oxidised copper minerals.

One of the obstacles to a successful exploitation of the copper ores of Sikkim or Darjeeling is the inaccessibility of the areas and the lack of adequate communications. A successfully established water-power scheme in either area would add considerably to the prospects of its copper deposits.

Hazaribagh district, Bihar and Orissa.

Several attempts have been made within the last 70 years to re-open the old Baragunda copper workings in the Hazaribagh district of Bihar and Orissa. In 1888 the Bengal Baragunda Copper Company turned out 218 tons of refined copper, but the assays of average samples of the ore are not inviting, yielding between 1 and 3 per cent. of copper.

Burma.

Copper is found at Bawdwin in the Northern Shan States of Burma, reserves of copper ore were reported in 1928 to amount to 350,000 tons averaging about 13 per cent. of lead; 8 per cent. of zinc; 7 per cent. of copper; and 18 ounces of silver to the ton. There is now a considerable and regular production of copper matte at the Namtu smelting works of the Burma Corporation, assaying on an average about 41 per cent. of copper, 35 per cent. of lead and 70 oz. of silver to the ton. This matte is being exported to Hamburg for further treatment. The annual output during the five years under review averaged 9,051 tons (*see* Table 34). Copper ore is also found in

the Myitkyina and Katha districts, but no regular operations are carried on in either, and no ore-bodies of any value have yet been proved.

Madras.

Old copper workings on an extensive scale are to be seen in Nellore, in the neighbourhood of Garimanipenta (Ganipenta), but are confined mostly to the surface. Some 14 tons of ore were produced during 1926 and 1927. The existence of payable ore at appreciable depths has never been investigated.

Mysore.

The 5 tons of copper ore raised in Mysore State in 1928 came from Biligiri in the Mysore district.

Rajputana and Nepal.

Copper has been mined at several localities in Jaipur, and deposits of unknown value are known to occur in Nepal.

Indian consumption of copper and brass.

That there is plenty of scope for the development of copper deposits in India to satisfy the Indian demand is seen by the magnitude of the imports of copper and brass. The average annual values of these for the period under review are shown in Table 35, together with the exports of Indian copper and brass wares (manufactured from imported metal), and the re-exports of foreign copper and brass. From these it is seen that the value of the average annual consumption has been Rs. 1,22,19,977 in the case of copper and Rs. 2,52,18,294 in that of brass, as against Rs. 2,09,07,779 and Rs. 2,70,10,600, respectively, in the previous quinquennial period.

TABLE 35.—*Average annual exports and imports of Copper and Brass for the five years 1924-25 to 1928-29.*

	COPPER.		BRASS.	
	Rs.	Rs.	Rs.	Rs.
IMPORTS	..	1,68,03,486	..	2,65,54,811
EXPORTS—				
Of Indian merchandise	41,72,679	..	11,91,564	..
Of Foreign merchandise	2,38,520	..	1,44,240	..
Of Government stores	1,72,310	..	713	..
TOTAL EXPORTS	..	45,83,509	..	13,36,517
INDIAN CONSUMPTION	..	1,22,19,977	..	2,52,18,294

Diamonds.

[E. H. Pascoe.]

Notwithstanding the reputation (stretching back even as far as Ptolemy in the European, and further in the Hindu, classics) which India has had as a diamond-producing country, the output of to-day is very small and comparatively unimportant. The diamonds of ancient days all came from the so-called Golconda mines. Golconda, as a fact, was merely the mart at which the stones were sold or bartered. The Koh-i-nur, presented to Queen Victoria on the annexation of the Punjab in 1849 and now one of the Crown jewels, is said to have been once in the possession of the Emperor Aurangzeb, and was, according to tradition, found somewhere near the Kistna river. The Regent or Pitt diamond, which figured in the State sword worn by Napoleon, is said to have come from the Kistna district. The places which, according to accounts, have been most productive in the past form three great groups, each in association with the old unfossiliferous rocks of probably pre-Cambrian age, known as the Purana group, and distinguished locally as the Cuddapah and Karnul systems in South India, and as the Vindhyan system in the northern part of the Peninsula.

Distribution in India.

The southern of the three groups of diamond occurrences includes localities, with apparently authentic records, in the districts of Cuddapah, Anantapur, Bellary, Karnul, Kistna and Godavari. Loose stones have been picked up on the surface of the ground, and found in deposits of alluvium and in workings that have been undertaken in the so-called Banganapalle stage of the Karnul series of strata.

Southern group of occurrences.

Although no official returns are available, private but unconfirmed reports indicate that every year a certain number of valuable diamonds are picked up after showers of rain in the neighbourhood of Wajra Karur in the Anantapur district of the Madras Presidency. One was recently found in a field north of the pipe, calculated of sufficient size to yield a table diamond of sixty carats, worth about a lakh of rupees.

During 1910-12, Mr. A. Ghose prospected a concession at Virapalle in the Karnul district. The bed of diamond-bearing conglomerate was found to vary between 3 inches and 2 feet in thickness

and to yield from $\frac{1}{8}$ to $\frac{1}{2}$ carat of diamond from each load of 16 cubic feet, most of the diamonds obtained being perfect crystals of fine quality and free from flaws. During the past ten years no returns of the output in Madras have been forthcoming, and the working of the mines appears to have been suspended.

Eastern group of occurrences.

In the second group of occurrences, in the Mahanadi valley, the stones have been found in the alluvium of the Sambalpur and Chanda districts, but, though strata similar to those of the Vindhyans and Karnuls are known in this area, no diamonds have been found in these older rocks.

Central Indian occurrences.

The third group of occurrences occupies a tract some sixty miles long by ten miles wide, with the Vindhyan conglomerates near Panna as the centre. The diamond-mining industry still persists in this area, both in the old conglomerate of Vindhyan age, and in the alluvium derived therefrom. The States in which diamonds are found are Panna, Charkhari, Bijawar, Ajaigarh, Kothi, Pathar, Kachhar, Baraunda, and Chobepur.

The following scale of strata will give an idea of the position of the diamantiferous beds with reference to the Upper Vindhyan rocks exposed in the Central India area—

BHANDER SERIES . . .	Upper Bhander sandstone. Sirbu shales. Lower Bhander sandstone. Bhander limestones. Ganurgarh shale.
	Diamantiferous horizon.
REWA SERIES . . .	Upper Rewa sandstone. Jhiri shales. Lower Rewa sandstone. Panna shales.
	Diamantiferous horizon.
KAIMUR SERIES . . .	Upper Kaimur sandstone. Kaimur conglomerate. Bijaigarh shale. Lower Kaimur sandstone.

The following is a summary of the principal results of a study by Mr. E. Vredenburg,[1] of the diamond-fields of Central India.

[1] *Rec. Geol. Surv. Ind.*, XXXIII, pp. 261-314 (1906).

In the neighbourhood of Panna the principal diamond-bearing stratum is a thin layer of conglomerate, locally known as *mulda*, lying between the Upper Kaimur sandstone and the Panna shales. The conglomerate is seldom thicker than two feet and does not form a continuous bed. Further east, in the neighbourhood of Itwa, the diamond-bearing conglomerate does not rest directly on the Kaimur sandstone, but is separated from it by a 20-25-foot bed of shales and limestone. Another diamantiferous conglomerate occurs above the Rewa sandstones and under the Bhander series. This conglomerate differs from that below the Rewa series in the abundance of pebbles of vein quartz, instead of the different varieties of jasper found so commonly in the main diamantiferous conglomerate near Panna.

The diamonds in these conglomerates, like the associated large pebbles of lighter rocks, are derived from older rocks, and the original home of the gem is still unknown, though a precise recognition of the associated pebbles will gradually indicate the direction in which the mother-rock once occurred and possibly still exists. The most characteristic pebbles in the diamond-bearing conglomerates are the jasper-pebbles derived from the Bijawar formation and the vein quartz similar to that traversing the Bundelkhand granites, the latter being especially abundant in the conglomerate lying above the Rewa sandstone.

Besides the diamonds lying still embedded in the conglomerates others are found in the neighbouring detritus derived from the disintegration of the Vindhyan beds. The workings are developed accordingly—some with a view to the removal of the undisturbed conglomerate, and others with the intention of recovering the diamonds included in the more recently distributed detritus.

The undisturbed conglomerate is often covered by considerable thicknesses of younger Vindhyan rocks, and is reached by workings which are often, but not always, deep; these may be called 'direct workings'. In other places the overlying younger rocks have been removed by weather agents, and the conglomerate thus exposed at the surface is available for 'shallow workings'. In the detritus removed from the original conglomerate and deposited in river-valleys the diamonds may be reached by superficial, shallow, or comparatively deep workings, and they may be all spoken of conveniently as 'alluvial workings'.

Production.

The figures returned for diamonds relate to the production in the Central Indian States of Panna, Charkhari and Ajaigarh, with the addition of Bijawar and Baraunda. The production during the five years under review is shown in Table 36, the average being 223·87 carats worth Rs. 36,237 as compared with 161·94 carats worth Rs. 92,124 during the previous five years.

TABLE 36.—*Production of Diamonds in Central India during the years 1924 to 1928.*

	Quantity.	*Value.*	Daily labour.
	Carats.	*Rs.*	Persons.
1924	66·16	*27,596*	540
1925	47·63	*14,598*	643
1926	68·60	*28,559*	490
1927	112·74	*44,943*	629
1928	823·80	*65,491*	779
Average .	*223·78*	*36,237*	*616*

Gold.[1]

[G. DE P. COTTER.]

The production of gold in the world during 1927 was 19,300,000 fine Troy ounces, valued at about £82,000,000. India, with a production of 384,272 ounces, produced only about 2 per cent. of the total. During the four years 1904 to 1907, India occupied the seventh position amongst the leading gold producing countries of the world; in 1908 she fell to the eighth position, the countries of higher production being the Union of South Africa, United States of America, Canada, Mexico, Russia, Rhodesia and Australia. Up to 1918, she still occupied the eighth position, but in 1920 she rose to the seventh position, Russia's production having decreased. In 1925, the production of gold in Russia was again higher than that of India, which again fell into the eighth position. She maintained this position up to 1927 (*see* Table 37).

[1] A general account of the gold occurrences of India and Burma is given in Dr. Maclaren's 'Gold' pp. 238-270 (1908); considerable use has been made of this in preparing this article.

TABLE 37.—*Production of Gold by the chief gold-producing countries during 1927.*[1]

Countries.	Fine ounces.
1. Union of South Africa	10,122,491
2. United States of America	2,117,253
3. Canada	1,852,785
4. Mexico	725,175
5. Russia	725,098
6. Rhodesia (Northern and Southern)	582,422
7. Australia	508,376
8. India	384,272
9. Japan	308,820
10. Gold Coast	171,585
11. Belgian Congo	137,055
12. New Zealand	129,601
13. Other countries	1,535,067
TOTAL	19,300,000

Provincial production.

Table 38 shows the provincial production for India during the five years under review. In 1904 no less than 98·2 per cent. (by value) of the Indian output was returned by Mysore, and 1·7 per cent. by the Nizam's Dominions, leaving only 0·1 per cent. as the production of districts directly under British administration. By 1908, owing to the development of reef mining in Dharwar and dredging in Myitkyina, the proportion derived from districts directly under British administration had risen to 2·7 per cent.; of the remainder, 94·4 per cent. came from Mysore and 2·9 per cent. from the Nizam's Dominions. During the quinquennium 1919-23, Mysore easily maintained her lead, and in 1923 produced 99·6 per cent. of the total. In 1928 Mysore produced all but 177 ounces of the total production, a proportion equal to 99·999 per cent. of the total. Dharwar (Bombay Presidency) ceased to produce in 1911, nor has this area been reopened since. In the quinquennium 1919-23 the returns from Madras Presidency (mainly Anantapur district) averaged 8,936 ounces annually, but the present period shows a decline ending in closure of the mines in 1927. The total amount produced from Anantapur in the present quinquennium was 7,259 ounces, giving an average annual yield of 1,452 ounces. The operation of the mines in Hyderabad ceased in 1921. There are no returns from Myitkyina.

[1] Figures taken from *The Mineral Industry of the British Empire and Foreign Countries* (Imperial Institute) Statistical Summary, 1925-27.

TABLE 38.—*Quantity and value of Gold produced in India during the years 1924 to 1928.*

PROVINCE.	1924 Quantity.	1924 Value.	1925 Quantity.	1925 Value.	1926 Quantity.	1926 Value.	1927 Quantity.	1927 Value.	1928 Quantity.	1928 Value.
	Oz.	Rs.	Oz.	Rs.	Oz.	Rs.	Oz.	Rs.	Oz.	Rs.
Bihar and Orissa—										
Singhbhum .	..	..	..	..	123·0	6,600	..	..	7·0	652
Burma—										
Katha . .	23·6	1,441	19·7	1,265	24·2	1,491	11·5	778	16·6	1,066
Upper Chindwin	43·2	3,194	13·4	1,266	122·4	11,127	48·2	4,169	54·7	4,741
Kashmir . .	..	..	..	..	46·7	1,995	48·0	2,048	60·0	2,520
Madras (a) . .	3,646·0	2,38,605	288·0	16,517	930·0	53,219	2,395·0	1,37,320	..	..
Mysore (a) .	392,578·2	2,51,54,948	393,512·8	2,22,36,295	382,899·3	2,16,39,632	381,723·0	2,16,54,394	375,886·0	2,12,72,297
Punjab . .	57·9	2,978	37·4	1,974	8·6	444	42·5	1,645	34·0	1,369
United Provinces	2·2	150	3·8	225	4·1	275	4·3	275	4·5	240
TOTAL .	**396,351·1**	2,54,01,316	**393,875·1**	2,22,57,562	**384,158·5**	2,17,64,753	**384,272·5**	2,18,00,629	**376,062·8**	2,12,82,585
Value in sterling .	..	£1,827,433 (£1= Rs. 13·9)	..	£1,676,501 (£1= Rs. 13·3)	..	£1,624,238 (£1= Rs. 13·4)	..	£1,626,913 (£1= Rs. 13·4)	..	£1,588,252 (£1= Rs. 13·4)

(*a*) Fine gold.

The production of the Mysore state is solely derived from the Kolar district and from a single vein or reef in that district—a reef averaging only some four feet in thickness and payably auriferous for a distance of little more than five miles.

[1] Vein gold: development of the Kolar field.

The development of the Kolar goldfield is one of the romances of modern mining. As has been the case with all other known auriferous deposits in Peninsular India the attention of Europeans was directed to this field by the occurrence of numerous old workings along the strike of the principal lode. In 1873, Mr. M. F. Lavelle of Bangalore obtained from the Mysore Government the concession to mine in the Kolar district, and after preliminary operations, during which he discovered that large capital would be required, he transferred his concession to the late Major-General D. de la Poer Beresford, who with some friends formed a syndicate known as the Kolar Concessionaires. In 1880, the Concessionaires secured the aid of the well-known firm of mining engineers, Messrs. John Taylor & Sons of London, and in that year were floated three out of the five companies that are still operating, namely, the Mysore, Ooregum, and Nundydroog companies, the Balaghat and Champion Reef companies being floated in 1881 and 1889 respectively. The features of the auriferous deposits were not at first grasped and much money was expended in mining in barren ground and amidst ancient workings, which were eventually found to reach a depth of 300 feet. By this time the resources of the various companies were mostly exhausted, and it was only a final effort of the Mysore Company that disclosed that the Champion lode persisted in depth, instead of being cut out in depth as was previously thought. By 1885 the success of the Kolar goldfield was assured, and in a short time a large and flourishing town arose and Kolar is now one of the model mining towns of the world, with modern conditions of life and a group of successful and efficiently managed mines, in which all the improvements of mining are brought to bear on the successful extraction of the gold quartz at increasing depths and under increasingly difficult conditions of work due to heat and rock pressures.

The deepest mines are Champion Reef and Ooregum, which have each reached a depth of considerably over 6,500 feet measured

[1] The following account of the Kolar goldfield during the quinquennium under review is taken from an unpublished report entitled 'A Brief Note on the Working of the Kolar Gold Field for the years 1924 to 1928' by H. Bocquet J.P., Chief Inspector of Mines in Mysore.

vertically and, at these levels, the quartz reef encountered is practically as rich as at any of the higher levels of these same mines, although the average grade of ore milled shows a perceptible decrease. The figures given below represent the yield in pennyweights of fine gold per short ton of the five mines in the years 1924 and 1928 respectively :—

	1924.	1928.
Mysore	10·10	9·70
Champion Reef	8·33	9·56
Ooregum	13·16	11·03
Nundydroog	8·81	9·87
Balaghat	14·72	12·69

Rockbursts continue to be a source of great anxiety and a very large percentage of the accidents underground are due to this cause. All the mines suffer more or less severely from them, but it is gratifying to record that the steps now taken to minimise their effects have, up to a certain point, proved successful. All the more important shafts are brick or concrete-lined while, in the stoping sections, ordinary heavy timbering and filling with waste rock have been superseded by packed cribsets and pack-walls, in spite of the steeper inclination—between 70° and 80°—of the reef.

Owing to their great depth and the existing high rock temperatures—between 118° F. and 122° F. in the lower workings—the problem of ventilation of these mines continues to be an extremely difficult one. It has been partly solved by sinking deep, circular, brick-lined shafts, 18 feet in diameter, from the surface with either elliptical or smaller circular shafts for the secondary stage, and by the use of large electrically driven fans to help the main air currents and smaller fans and blowers for special places. There are five of these brick-lined shafts on the field sunk from surface, of which that on the Ooregum mine, completed about 5 years ago, is the deepest, *viz.*, 4,680 feet vertical. In spite of the increased volume of air, greater velocity, better circulation and decreased humidity, some of the mines have become uncomfortably hot in the lower levels—a state of affairs in which it is difficult to foresee any improvement.

The ore is not refractory and yields its gold to a simple combination of amalgamation and cyaniding, being reduced for the most part to a state of slime ; 'all-sliming' is gradually becoming general.

During the five years under review, the annual tonnage crushed gradually decreased from 686,273 tons in 1924 to 652,949 tons in 1928. (These figures, returned by the Chief Inspector of Mines for Mysore, are in short tons).

In 1905, the gold yield reached a maximum value of £2,373,457, the largest ever recorded in the history of the field. Since then there have been noticeable fluctuations in the value of the output; in 1923 it sank to £1,752,334 but again recovered slightly in 1924. Since then, however, it has been gradually declining. For the five years under review, the value of the gold extracted was £8,381,439 which is less by £1,325,116 than the value for the preceding five years.

In 1905, the dividends paid reached their maximum value, *viz.*, £1,066,615, for the whole period of the industry; there was then a marked annual decline to £749,398 in 1912. From that date a further decline commenced, the lowest figures reached being £196,624 in 1919. Since that date, there has been a gradual rise with moderate fluctuations, the dividends paid during the five years under review being £1,543,393 compared with £1,387,770 paid during the previous five years. For the same period, dividends have been paid by all the five working mines, *viz.*, the Mysore, Champion Reef, Ooregum, Nundydroog and Balaghat.

No exploratory or mining work for gold has been done by other companies on the Kolar field or elsewhere in the Mysore state during the last five years.

The introduction of electric power from the Cauvery falls, the first stage of which was completed about the middle of 1902 and designed for the conveyance of 4,000 H. P. over a double line 92 miles long, has gradually been extended and in 1928 the generating plant supplied 151 motors aggregating 18,811·5 N.H.P. This supply is continuous, even in years of lean rainfall, now that the Krishnarajasagara dam is completed.

The Kolar Mines Power Station, Ltd., formed in 1903, continues to supply power for electric lighting and the driving of motors used intermittently, the motive power for working the generators being steam. In 1928, the number of Board of Trade units supplied for this purpose amounted to 13,790,037.

The water-supply scheme from the Bethmangala tank (some 6 miles from the field), undertaken by the Mysore Government, has ensured a regular supply of filtered water sufficient for all purposes. The pumping plant has been electrified.

Table 39 shows the various statistics of production for the Kolar field both for the period under review and for the previous quinquennium.

TABLE 39.—*Statistics of production, Kolar goldfield.*

YEAR.	Tonnage crushed.	Value of gold extracted.	Dividends paid.	Royalty paid.
		£	£	£
1919	702,423	1,866,715	196,624	98,157
1920	673,152	2,189,290	339,784	117,958
1921	641,474	2,110,451	312,098	108,375
1922	672,963	1,787,765	254,620	95,754
1923	650,115	1,752,334	284,644	91,758
TOTAL FOR 1919-23 (REVISED FIGURES).	3,340,127	9,706,555	1,387,770	512,002
1924	686,273	1,833,556	305,064	95,808
1925	692,933	1,684,619	309,791	91,129
1926	640,955	1,631,412	309,168	88,904
1927	638,556	1,627,777	311,917	88,846
1928	652,949	1,604,075	307,453	87,531
TOTAL FOR 1924-28 .	3,311,666	8,381,439	1,543,393	452,218

	£
Total value of gold produced from 1882 to 1928 .	68,748,923
Total value of dividends paid from 1882 to 1928 .	21,851,718
Royalty paid to Mysore Government from 1882 to 1928 inclusive	3,626,286

The work on the field is carried on by Europeans, Anglo-Indians and Indians in the following proportions, calculated from the number employed during the year 1928, the latest for which figures are available :—

	Per cent.
Europeans (including Italian miners)	1·8
Anglo-Indians	2·0
Indians : men	85·9
Indians : women (employed only on the surface) . . .	6·9
Indians : children (under 12 years : employed only on the surface)	3·4

The following table indicates the risks attendant on mining in the Mysore state :—

TABLE 40.—*Fatal accidents in Kolar mines for the years 1924 to 1928.*

YEAR.	Number of persons employed.	Death rate per 1,000 employed.	Death rate per £100,000 worth of gold obtained.
1924	19,836	3·38	4·01
1925	19,347	3·62	4·18
1926	18,742	2·45	2·82
1927	18,918	2·64	3·08
1928	18,826	2·28	2·68
Average .	*19,134*	*2·87*	*3·35*

In 1901, a company was floated to work the Hutti goldfield situated on the Maski band of Dharwar schists in the Lingsagar district of the Nizam's Dominions. This company, the Hutti (Nizam's) Gold Mines, Limited, was an offshoot of the Hyderabad (Deccan) Company. Crushing with ten head of stamps was commenced in 1903, with a production of 3,809 oz. of gold that year. Subsequently the number of stamps was increased to 30. The average output during the period 1914-1918 was 16,539 oz. valued at £63,463. During the quinquennium 1919-1923, the mines were worked up to the first quarter of 1920, when operations ceased.

Hyderabad (Nizam's Dominions).

In 1905, another company known as the Topuldodi (Nizam's) Gold Mines, Limited, with a capital of £90,000 was formed to take over from the Hutti Company an option held on the Topuldodi block in the Raichur district of the Nizam's Dominions. During 1908, 2,132 oz. of gold, worth £8,319, were produced. But as the ore developed in the mine proved to be of very low grade, the mine was closed down, and its assets transferred to the Hutti Company.

A third Indian field on which work was actively prosecuted during the earlier part of the period 1909-13 is the Dharwar field, situated on the Gadag band of Dharwar schists, partly in the Dharwar district and partly in the Sangli state, both of which lie in the Bombay Presidency. In spite of the expenditure of much capital

The Dharwar gold-field.

in very thorough development operations the reefs were found too poor to work and the mines were abandoned in 1911.

Anantapur.

In 1902, Mr. E. W. Wetherell, of the Mysore Geological Department, discovered a previously unknown belt of Dharwar schists stretching in a north and south direction for some 32 miles through the Anantapur district of Madras, but just touching the north-east corner of the Pavagada *taluk* of the Tumkur district of Mysore. Several large quartz reefs occur in this belt, and near the village of Ramgiri old gold workings were found. The gold occurs in quartz veins principally in chloritic and argillaceous schists. A company called the Anantapur Gold Field, Limited, was formed in 1905. In 1908, it transferred a portion of its holdings (the Buruju block) to a new company, the North Anantapur Gold Mines, Limited, and other portions (South Jibutil block and, subsequently, North Jibutil block) under option to the Nundydroog Company of Mysore. The option was exercised and the Jibutil Gold Mines of Anantapur, Limited, was formed to take over the properties from the Anantapur Gold Field Company on payment of £5,000 in cash and 160,000 fully paid shares, of which 20,000 went to the Nundydroog Company. The Jibutil Gold Mines of Anantapur ceased mining operations in September, 1924, when notice was given to Government to terminate their mining lease. A small quantity of gold was extracted from the dumps in 1925, after which operations were suspended. This company carried out a considerable amount of development work in the preceding quinquennium (1919-23). Treatment was effected at the North Anantapur Company's plant.

The North Anantapur Gold Mines, Limited, after carrying on vigorous development work, ceased mining operations on the original area in July, 1922. These mines, which were situated in the Dharmavaram *taluk* of Anantapur district, produced 44,678 ounces of fine gold during the quinquennium 1919-1923. In 1925, small quantities of gold were extracted from the dumps by cyanide treatment, but work was finally suspended in June, 1925. The total fine gold produced from these mines since the commencement of operations has been 136,739 ounces. Meanwhile, as a result of prospecting operations in 1922, by this company, ancient gold workings were discovered in the Gooty *taluk* of the Anantapur district some 35 miles north of the old North Anantapur Mine. Exploratory work was carried on in the area and finally, in 1926, the North Anantapur

Gold Mines, Limited, applied for a mining lease near the villages of Rampuram and Venkatampalli in Gooty *taluk*. Gold was first extracted from this area in 1926. The extraction of gold ceased in August, 1927, after which date mining operations were permanently suspended.

The Nilgiris.

The Nilgiris, after many vicissitudes, have ceased to be a mining area: but some native workers are reported to be making a living by roughly treating the waste heaps, from which they extract a small quantity of gold.

Salem district.

Auriferous quartz was reported to have been found at Matagondapalli about 10 miles south-west of Hosur in the Salem district. An assay done in the Geological Survey Laboratory of some of the quartz from this area, however, showed no trace of gold.

Gold in sulphide lodes.

Besides occurring in the free state in quartz veins, as in the areas noticed above, gold is sometimes found in sulphide lodes enclosed in the sulphide minerals. Thus, gold occurs in Sikkim among the mixed sulphide lodes (chalcopyrite, pyrite, pyrrhotite, blende, etc.) and in the copper-bearing lodes of Sleemanabad in the Jubbulpore district of the Central Provinces. Assays in the latter case have occasionally shown amounts as high as 15 dwts. per ton.

Alluvial gold.

Alluvial gold-washing is carried on in Assam, Bihar and Orissa, and many other places in the Indian Empire, but the fact that the washers invariably combine this pursuit with other occupations, and because the individual return is exceedingly small and is locally absorbed for jewellery, complete returns are not available. These, so far as they go, give little hope of the discovery of rich alluvial deposits in peninsular India, or indeed in any part of India affected by the monsoon rains and dependent on them alone for the supply of the rivers. For concentration of gold, a comparatively equable current is essential —a condition rarely obtainable in the gravel river beds of India, where alone gold would be found, for these are almost dry in the cold weather and roaring torrents in the rains. The greater possibilities of dredging on the Irrawaddy appear to arise from the fact that the waters of that river are derived from ranges where, even in the cold weather, there is a heavy rainfall. But, in the case of the Irrawaddy, the flood waters, which prevail during the rains, have in the past seriously interfered with dredging operations.

In Upper Assam, tributaries such as the Subansiri; that flow from the north into the Brahmaputra, carry small quantities of gold.[1]

Assam.

One small bar near the mouth of the Subansiri gorge was found to contain more than 1 dwt. per cubic yard; but the quantity of gravel available was very small. It is probable that some of the gold of this region is derived immediately from the Tipam (Siwalik) sandstones, and that the source of the gold in the Lohit branch of the Brahmaputra is to be sought in the metamorphic rocks of the Miju ranges.

In the Chota Nagpur division of Bihar and Orissa, alluvial gold is found widely distributed, but the gold-washing is of most importance in the Singhbhum and Manbhum districts, and is chiefly confined to the valley of the Subarnarekha ('golden-streaked') river and its tributaries. The average earnings per person employed amount to only As. 1½ to 2 a day.

Chota Nagpur.

The result of the work of Dr. Maclaren[2] and of other members of the Geological Survey was to show that nowhere in Chota Nagpur had gold deposits—either alluvial or vein—been found worth working on European lines. Not long ago, however, interest in that area revived, and The Dalbhum Gold and Minerals Prospecting Company, Limited, was promoted to work gold mines in Dalbhum State. A modest output of 450 ounces was first made in 1915, but rose in 1917 to 2,462 ounces: it fell to 2,085 ounces in 1918, and to 173 ounces in 1919. The mines were finally closed in 1920.

The native gold-washing industry is carried on from year to year in several districts of Burma, usually by only a few people in each district; the number so engaged varies from year to year partly in accordance with the character of the seasons. No accurate figures of production are available. In Table 38, returns are shown of production from the Katha and Upper Chindwin districts. In 1928, the total amount from these districts was 71·3 ounces. Besides the gold produced from the above districts, small quantities of the order of say 10 to 15 ounces are produced from the Lower Chindwin district from tributaries of the Yama, Yewa, and Hmyaing *chaungs*[3]; washing is carried on for about two months during the

Burma: native gold washing.

[1] *Rec. Geol. Surv. Ind.*, XXXI, pp. 179-232 (1904).
[2] *Ibid*, pp. 59-91.
[3] *Ibid*, LXII, p. 52 (1929.)

rains, and the gold-washers are said to win about 4 annas worth of gold per day. Similar gold-washing operations of minor importance are carried on in the Myitkyina district from the sands of the Uru river, between Pantin and Namon.[1] The Uru boulder conglomerate is also washed for gold by Shan women, who can collect from 6 to 7 annas worth in a morning's work.

Burma gold-dredging: the Irrawaddy.

The former gold-dredging on the upper reaches of the Irrawaddy was largely due to the enterprise of Mr. W. R. Moore, who, in association with Captain J. Terndrup, was granted in 1901, a five years' license for dredging within the bed of the river for a stretch of some 120 miles from the confluence above Myitkyina to the mouth of the Taiping above Bhamo. In 1904, the license was extended for a period of thirty years and restricted to about 88 miles of the river from Sinbo to the confluence, while sanction was given at the same time to transfer the concession to the Burma Gold Dredging Company, which was registered in Rangoon in 1903. In 1907, permission was given to alter the limits of the concession by exchanging 15 miles of the lower end for 10 miles along the N'mai-hka and 5 miles along the Mali-hka. Application was subsequently made for a further exchange of the Irrawaddy part of the concession for 15 miles along the eastern river N'mai-hka. This company was liquidated in 1911, and a new company formed, called the Burma Gold Dredging Company, 1911, Limited.

For the greater part of the period 1909-1913, five dredges were at work, but the results did not come up to expectations. Expenses were cut down considerably by the substitution of Kachin for Australian skilled labour, but the output was still considerably below that of 1909; this was attributed to the poor quality of the wash remaining to be worked in the bed of the river. The average annual outturn for the period 1914-1918 was 1,951 ounces. After 1918, there was no production of gold, and the company closed down dredging operations altogether.

The gold-bearing alluvium is coarse gravel with the gold disseminated fairly uniformly. The average value of the gravel was about 3 grains (6 annas) per cubic yard. Small quantities of platinum and platinoid metals are recovered with the gold.

[1] *Rec. Geol. Surv. Ind.*, LXII, p. 53 (1929.)

The alluvial stretches of the Chindwin river have been found to contain gold at many points, but systematic prospecting has in most cases shown them to be valueless as dredging propositions, although they are a source of income to the native gold washers.[1] A concession for 180 miles of the Lower Chindwin river, stretching from Minsin to Homalin, was granted about 1903, to the Burma Mines Development and Agency, and in 1905, transferred to the Mandalay Gold Dredging Company. A dredger was obtained, but became stranded while being towed up the Chindwin river, and no further work was attempted.

The Chindwin.

The Uru, a tributary of the Upper Chindwin, has also been prospected for alluvial gold, but with little success so far.

In 1905, the Namma Gold Dredging Company, Limited, with a capital of £70,000 (£55,000 issued, of which £30,000 went to vendors) was floated in London to work two stretches of the Namma river, a tributary of the Salween, in the Shan States. A careful preliminary investigation had indicated the existence of approximately 40,000,000 cubic yards of gravel averaging 5·43 grains of fine gold per cubic yard. A steam dredger was purchased and floated in a paddock on the Upper Namma, but it was then found that the deposit was unfitted for this mode of exploitation. It consists of gravel and boulders embedded in a stiff clay, hardened by calcareous tufa derived from the limestone forming the sides of the valley, and is therefore not sufficiently loose to enable the buckets of the dredger to excavate it. The venture, therefore, ended in failure.

The Namma.

The alluvial gold deposits of Loi Twang in the Shan States, worked by native washers, have been examined in detail by Mr. T. D. La Touche and found to be of no commercial value.[2] Alluvial deposits examined by Dr. J. C. Brown, in Mong Long, Hsipaw State, were also found to be too poor generally to be worth exploitation, although small patches were found to contain occasionally over 9 grains of gold to the cubic yard.[3]

Other Burmese rivers to which attention has been directed by European prospectors, without any tangible results so far, are the More Chaung, Taiping, and Shweli, tributaries of the Irrawaddy;

[1] H. S. Bion; *Rec. Geol. Surv. Ind.* XLIII, p. 341 (1913).
[2] *Ibid*, XXXV, pp. 102-113 (1907).
[3] *Ibid*, XLII, p. 37 (1912).

the Upper Chindwin ; the Salween ; and the streams of Tavoy, where gold has been found associated with tinstone.

The Central Provinces.

Alluvial gold occurs in the sands and gravels of many of the rivers and streams of the Central Provinces, particularly in those that drain down from or run over areas where the ancient crystalline and metamorphic rocks crop out. According to an 'Industrial Monograph on Gold and Silverware in the Central Provinces' by H. Nunn, I. C. S., published at Allahabad in 1904, which contains also the best account yet published of the native gold-washing industry of that province, gold-washing has been carried on at various times in the following districts : –Balaghat, Bhandara, Bilaspur, Chanda, Jubbulpore, Mandla, Nagpur, Raipur, Sambalpur, and Seoni. From the report quoted it appears that in addition to the washers of auriferous sands, there are people engaged in a cognate industry, consisting of the extraction of gold and silver particles, called in England 'lemel.' from the dust of a *sunar's* shop and furnace by a two-fold process, first of actual winnowing, and then of washing in a river. The resultant gold is treated by refining processes. The persons practising this 'lemel' washing, which is recorded for the Balaghat, Bilaspur, and Hoshangabad districts, are Mahomedans, and it is desirable to distinguish their occupation from that of the gold-washers proper, although there is doubtless at times a certain overlapping of the two occupations. The gold-washers are variously known in different parts of the province as *jhoras*, *jharias*, *sonjharas*, *sonjharias*, and *sonzaras*. The report cited gives a full account of the methods of washing and treating the gold as practised in the Tirora *tahsil* of the Bhandara district. The whole gold industry of the Central Provinces, however, is small and no reliable figures for output are available. It is not likely that more than 200 ounces are won annually.

Kashmir.

Washing for alluvial gold is practised along the valley of the Indus in the Gilgit and Baltistan divisions of Jammu and Kashmir State. In Skardo (Baltistan) and in the Indus river in Gilgit the washing of ancient gravels is carried on on quite an extensive scale. In the old river terraces of the Dras valley actual mining operations have in former years been undertaken to excavate the gold-bearing bands. There are no figures for production in the years 1924 and 1925. In 1928, the production was 60 ounces. At Kargil in Ladakh gold-washing

was carried on, and very small quantities of gold extracted in 1926 and 1927, (the gold extracted in 1927 was valued at 10 rupees) but there are no returns for 1928. A small quantity of alluvial gold is said to have been obtained formerly by Tibetans from sub-recent gravels on the Para river on the border between Rupshu and the Tibetan province of To-tso.[1]

Punjab.

Gold washing is carried on also in some of the Punjab rivers, especially the Indus, in the Attock, Ambala, and Jhelum districts, and the production for the quinquennium totals 180·6 ounces, giving an average annual figure of 36·1 ounces. In 1928, out of a total production of 34 ounces, 32 ounces came from Attock.

United Provinces.

In the United Provinces the gold-washing industry was reported in 1904, as employing about 100 workers in the Nagina *tahsil* of Bijnor district, but no returns are available of recent years from this area. The small quantities of gold reported in Table 38 represent the result of washings of alluvial gold from the Sona Nadi close to the south-west border of British Garhwal, near Kalagarh, where the river passes from British Garhwal into the Bijnor district. Alluvial gold has in former years been reported also from Naini Tal district. The total production during the quinquennium was 18·9 ounces.

Graphite.

[E. L. G. CLEGG.]

Mode of occurrence.

Graphite occurs in small quantities in various parts of India—in the so called khondalite series of rocks in the Vizagapatam hill-tracts and adjoining Chhattisgarh Feudatory States, in a corresponding series of rocks in Coorg, in the Godavari district of the Madras Presidency, in the Ruby Mines district in Upper Burma, and in Travancore. It has also been discovered in Sikkim, where a graphite vein, averaging about 13 inches in thickness, was found during the prospecting operations conducted by Messrs. Burn and Company at about half a mile to the north of the road from Tsüntang to Lachen. The quality of the mineral is said to be good, large bulk samples

[1] H. H. Hayden; *Mem. Geol. Surv. Ind.*, XXXVI, p. 102 (1904).

having given a return of 93 per cent. of graphite. Other veins of graphite are known to occur in the area, but have not been examined in detail.[1] It is also found in Ajmer-Merwara (Rajputana), and that district and Kalahandi and Patna in Orissa were responsible for a slight revival of the industry, which had died out in the year 1912. That industry has, however, again become dormant.

The graphite deposits of Travancore occur under conditions similar to those of Ceylon, whose rocks are but a continuation of the charnockite series and associated rocks of South India. The Ceylon graphite has been made the subject of an elaborate study by E. Weinschenk, who regards it as of igneous origin,[2] a conclusion in agreement with its occurrence in South India.[3] Small quantities of graphite have been extracted in Godavari and Vizagapatam but formerly practically the whole of the Indian production came from Travancore, where the average output used to be about 13,000 tons annually. Owing to difficulty of working at increased depths, however, the mines were no longer found to pay and were shut down in 1912. In 1915, the impossibility of obtaining graphite from abroad threw India on to her own resources; an indigenous supply again became necessary, various known deposits were opened up and there was an output of 1,318 tons in 1916. Most of this came from Rajputana and, like the Kalahandi material, is derived from raw material of comparatively low grade.

Production.

The occurrence of graphite in khondalite deserves further notice. One of the most prominent components of the rock formations in the Eastern Ghats facies of rocks found in Orissa and the Madras Presidency is the khondalite series, khondalite being a schist composed of quartz, sillimanite, garnet, and graphite. It is not surprising, therefore, to learn that deposits of graphite of possible economic value—bands, veins and pockets—are sometimes found in association with this series. Owing possibly to the comparatively inaccessible and undeveloped character of this part of India, only a few deposits of graphite of very moderate value have, however, hitherto been discovered—in the states of Kalahandi and Patna.

[1] According to a report by C. Wilkinson, communicated by the late Mr. A. Whyte of Raniganj.

[2] Die Graphitlagerstatten der Insel Ceylon. *Abhand, d.k. Baier. Akad.*, 1901, XXI, pp. 279-335.

[3] Holland. The Charnockite Series, *Mem. Geol. Surv. Ind.*, XXVIII, p. 126 (1900); and the Sivamalai Series, *op. cit.*, XXX, p. 174 (1901).

with recorded occurrences in the states of Athmallik and Sonpur, but other discoveries must be expected in the future when this tract becomes better known. In Kalahandi State graphite deposits have been found at two localities. At Koladi Ghat bands 12 to 20 inches thick have been met with in clay resulting from the decomposition of khondalite, whilst at Densurgi bands of calcareous graphite occur in a decomposed gneiss, which in its fresh condition was probably a garnet-graphite-biotite-gneiss.

Graphite deposits have also been found at Daramgarh and Domaipali in Patna State in graphite schists associated with garnetiferous gneissose schists, doubtless a variety of the khondalite series. Assays of specimens and samples from Densungi in Kalahandi and Dharamgarh, Marna (2 miles west of Patna) and Dundel in Patna State have been made with the following results:—

	Densungi.		Dharamgarh.		Marna.		Dundel.	
	1	2	3	4	5	6	7	8
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Sulphur	..	..	trace.	..	..	..	..	..
Moisture	..	1·12	0·38	0·42	·79	0·14	0·23	1·23
Volatile matter . .	6·33	3·89	0·38	0 89	0 61	2·08	2·15	3 58
Carbon dioxide . .	..	..	10·60	12·14	..	..	..	..
Fixed carbon (diff.) .	65·22	63 12	40 95	37·00	79·91	69·67	63·70	54·73
Ash	31·21	31·87	47·69	49·55	16 69	28·11	33 87	40·47

Sample 1 was assayed in the laboratory of the Geological Survey of India, and the remainder at the Imperial Institute. The latter samples were forwarded to an expert for report on their commercial value. He reported that they had not enough binding quality to be used for the manufacture of crucibles, but that, if obtained sufficiently pure, such graphite might be used for crucibes which were. subjected to one heating and then ground up and remodelled. During the war, however, the difficulty of obtaining graphite from abroad led to the opening up of the Kalahandi deposits by the Indian Graphite Company (Messrs. Bird & Co.). The product was transported to Bisra for treatment and there picked by hand and sorted into needle (crystalline) and amorphous varieties, crushed

and sieved, and put on the market as foundry graphite in two grades. the needle variety being used for the production of the higher grade, The output from Orissa States rose from 16 tons in 1915, to 252 tons in 1916, and fell to 122 tons in 1919, and 60 tons in 1920, since when there has been no production from Orissa. The reason for the decline was the high cost of transport of the raw graphite from the mines in the Kalahandi and Patna states to the refinery, more than 120 miles of which had to be traversed by bullock cart. However, the new Raipur-Vizianagram railway line, which is now under construction, will pass within 15 miles of the deposits, so that a revival of the industry in this area may be expected.

Graphite has also been recorded from Durdura in Sonpur State and from Athmallik State. No details are known as to the mode of occurrence at these two localities, but it is significant that the khondalite series is prominently represented in Athmallik and probably in eastern Sonpur.

The earlier outputs from Godavary and Vizagapatam were presumably also from the khondalite series.

In Chota Nagpur graphite has been recorded from the Palamau and Monghyr districts in graphite schists and gneisses, but none of these occurrences has yet proved to be of economic value. A small production of graphite was reported from the Betul district of the Central Provinces in 1920 and 1921.

There has been no production of graphite reported in India during the period under review.

Ilmenite.

[W. A. K. Christie.]

Ilmenite, titaniferous iron ore, occurs as a common accessory mineral in many of the crystalline rocks of peninsular India. It is occasionally found in masses of some size in the mica pegmatites of Bihar and Orissa. It accompanies wolfram at Degana in Rajputana. Ilmenite is plentiful in concentrates from Tavoy and other parts of Burma. About 3 miles south of Kishangarh in Rajputana large crystals of ilmenite, 2-3 inches in diameter, are found associated with clear calcite crystals forming a broad vein in the granitoid gneiss. This ore was at one time smelted in the local native furnaces.

But it is in the black sands of the Travancore coast that ilmenite occurs most plentifully in India. The production of Travancore for the last five years has progressed by leaps and bounds, and by 1927, India had become the largest producer of ilmenite in the world.

TABLE 41.- *Production of Ilmenite in Travancore in the years 1924 to 1928.*

Years.	Tons.	*Value.*
		£
1924	641	*1,381*
1925	328	*192*
1926	4,236	*7,5[illegible]*
1927	17,809	*[illegible],443*
1928	25.307	*41,557*

The Travancore black sands usually called monazite sands until the decline of the gas mantle industry rendered their content of that mineral relatively unimportant have been described by G. H Tipper.[1]

They occur sporadically along the shore line from Nindikarai, north of Quilon, on the west coast to Cape Comorin, and then round the east coast to Liparum, a distance of about a hundred miles. Tipper ascribes their peculiar accumulation to wave sorting on a beach of abnormal slope during quiescent north-east monsoon periods. Dunes, too, have frequently been formed by the action of the wind on the sun dried sands of the beach. The principal firm now working the deposits is the Travancore Minerals Company, Limited, whose factory is at Manavalakurichi (8° 8′; 77° 18′). The beach sand from which ilmenite is being extracted is said to contain as much as 70 per cent. of that mineral. The sand is fairly hard-packed, but damp, and is worked to a depth of about eight feet. It is dug out by hand into baskets and dried in the sun. It is then treated by screens, concentrating tables and magne-

[1] *Rec. Geol. Surv. Ind.*, Vol. XLIV, p. 186 (1914).

tic separators, and thus freed from zircon, monazite, rutile, garnet and several other minerals. The ilmenite is taken by road five miles W. N. W. to Kolachel, where it is loaded into lighters and delivered to ships anchored off the coast.

The chief use of ilmenite is in the manufacture of white paints consisting of titanium dioxide, either pure or, more usually, in conjunction with zinc oxide, barium sulphate, calcium sulphate or lithophone. The opacity or hiding power of titanium dioxide is very high; it is not poisonous and it has great resistance to corrosion. For a comparison of its properties with those of other white pigments reference may be made to papers by A. W. Hixson and W. W. Plechner[1] and by C. S. Fox.[2]

Iron.

[H. Cecil Jones.]

Production.

Bihar and Orissa, the Central Provinces and Mysore are the only parts of India in which iron-ore was mined during the period under review for the production of iron and steel by European methods. In Burma a considerable amount of ore, limonite and hæmatite, is won by the Burma Corporation, Ltd., at Wetwun, near Maymyo, but this is entirely for use as a flux in the lead smelting operations at Namtu. Table 42 shows the annual raisings of iron-ore in Bihar and Orissa during the last fifteen years. The raisings suddenly increased in 1911 by nearly 300,000 tons, the total rising from 42,653 tons in the preceding year to 342,342 tons in 1911. This was due to the operations of the Tata Iron and Steel Company, Ltd., the first stage of whose works at Jamshedpur (formerly known as Sakchi) was completed towards the end of that year; large quantities of iron ore were therefore raised from their Gurmaisini[3] deposits in Mayurbhanj State with a view to bringing the blast furnaces into operation. For the period 1911 to 1918 the yearly raisings of iron-ore in India were of the same order of magnitude, but during the last ten years there has been a big increase in the yearly raisings and, as will be seen from Table 42, the production of iron-ore for the last five

[1] *Chem. Met. Eng.*, Vol. XXXVI, p. 76 (1929).
[2] *Trans. Min. Geol. Inst. Ind.*, Vol. XX, p. 216 (1926).
[3] 'Gurumaishini' 'Gurumahisani', and other spellings.

TABLE 42.—*Production and value of Iron-ore produced in India during the years 1924 to 1928.*

	1924		1925		1926		1927		1928	
—	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*
	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*
Bihar and Orissa	1,302,812	*32,36,497*	1,435.558	*41,13,585*	1,594,577	*44,14,639*	1,736,060	*47,23,662*	1,956.621	*51,72,547*
Burma	59,014	(a) *2,36,056*	51,617	(a) *2,06,468*	48,089	(a) *1,92,356*	61,062	*2,44,245*	74,813	*2,99,252*
Central Provinces . . .	68,361	*3,73.702*	1,037	*4.152*	972	*3,957*	918	*3,846*	934	*3,972*
Mysore	14,958	*39.324*	56 218	*1,54,000*	(b) 15,427	*73,273*	48,465	*1,28,695*	23,624	*58,841*
Other Provinces and States . .	168	*1.001*	148	*866*	230	*1,406*	230	*1,410*	..	..
TOTAL .	1,445,313	*38,86,580*	1,544,578	*44,79,101*	1,659,295	*46,55,666*	1,846,735	*51,01,861*	2,055,932	*55,34,607*
Total value in sterling .	..	*£279,610* (£1 = Rs. 13·9)	..	*£336,775* (£1 = Rs. 13·3)	..	*£349,676* (£1 = Rs. 13·4)	..	*£380,735* (£1 = Rs. 13·4)	..	*£413,060* (£1 = Rs. 13·4)

(*a*) Estimated.
(*b*) Excludes 1,909 tons of hæmatite quartzite.

TABLE 43.—*Iron-ore raised in Bengal and Bihar and Orissa during the years 1914 to 1928.*

Year.	Burdwan.	Singhbhum.	Sambalpur.	Mayurbhanj.	Keonjhar.	Puri.	TOTAL QUANTITY
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1914	1,204	151,662	617	249,910	..	48	403,441
1915	2,243	127,040	386	240,269	..	53	369,991
1916	..	150,258	343	240,520	..	55	391,176
1917	..	184,815	377	195,621	..	..	380,813
1918	..	120,363	402	338,903	..	..	459,668
1919	..	104,728	945	423,599	..	..	529,272
1920	..	113,008	1,010	403,359	..	..	517,377
1921	..	237,173	797	651,495	..	..	889,465
1922	..	215,746	798	378,134	..	..	594,678
1923	..	218,584	632	507,225	..	..	726,441
1924	..	305,238	654	996,920	..	..	1,302,812
1925	..	477,580	703	957,275	..	..	1,435,558
1926	..	552,079	569	1,041,929	..	..	1,594,577
1927	..	1,007,037	561	692,137	30,325	..	1,736,060
1928	..	1,131,746	21	683,193	141,361	..	1,956,621
Average .	*1,723* (2 years)	*339,801*	*568*	*533,386*	*85,843* (2 years)	*52* (3 years)	885,863

years has been steadily on the increase. In the last quinquennial review it was stated that the production of pig-iron in Mysore was commenced in January, 1923 and that the daily output was between 40 and 45 tons. The figures denoting the quantity of ore raised were not available at that time but have been returned since as 16,669 tons. The output has been variable since, being as high as 56,218 tons in 1925, and as low as 14,958 tons in 1924.

In the last quinquennial review it was noted that the Indian Iron and Steel Company, Ltd., were obtaining iron-ore from the Central Provinces as they were unable to get sufficient ore from their Guà mines in Singhbhum, mainly owing to transport difficulties. These difficulties were overcome in 1924, and the raising of iron-ore in the Central Provinces dropped from 68,361 tons in 1924, to 1,037 tons in 1925; it has since decreased to 928 tons in 1928, the whole of this total being used in the indigenous smelting industry. In the cold weather of 1926-27 the Tata Iron and Steel Company,

Ltd., commenced mining ore at their new mine at Noamundi in Singhbhum, 156,425 tons of ore being mined. In the following year the output from this mine was 507,580 tons.

The iron-ore raised in Sambalpur by the local *lohars* dropped suddenly in the last half of the period under review from 561 tons in 1927, to 21 tons in 1928.

Since the last quinquennial review, iron-ore has been mined by the United Steel Corporation of Asia, Ltd., in Keonjhar State, the output at present being taken by the Indian Iron and Steel Co., Ltd.

General character of the iron-smelting industry.

The pages of the *Records* and *Memoirs* of the Geological Survey for the past fifty years contain ample evidence of the attention that has been paid to the iron-ores of India, but it is only within the last few years that any successful attempt has been made to establish an iron and steel industry on modern lines. On the other hand, iron-smelting was at one time a widespread industry in India, and there is hardly a district away from the great alluvial tracts of the Indus, Ganges, and Brahmaputra, in which slag-heaps are not found, for the primitive iron-smelter finds no difficulty in obtaining sufficient supplies of ore from deposits that no European iron-master would regard as worth his serious consideration. Sometimes he will break up small friable bits of quartz-iron-ore schist, concentrating the ore by winnowing the crushed materials in the wind or by washing in a stream; sometimes he is content with ferruginous laterites, or even with the small granules formed by the concentration of the rusty cement in ancient sandstones. In ancient times the people of India seem to have acquired a fame for metallurgical skill, and the reputation of the famous *wootz* steel, which was certainly made in India long before the Christian era, has probably contributed to the general impression that the country is rich in iron-ore of a high-class type. It is true that throughout the Peninsula, which is so largely occupied by ancient crystalline rocks, quartz-hæmatite and quartz-magnetite schists are very common in the Dharwarian system, the system of rocks that, lithologically as well as stratigraphically, corresponds approximately to the Lower Huronian of America. But most of these occurrences consist of quartz and iron-ore so intimately blended that only a highly siliceous ore of a low grade can be obtained without artificial

concentration. These occurrences of quartz-iron-ore schist are so common in India that newly recorded instances are generally passed over as matters of very little immediate economic interest. During the past few years, however, ore-bodies of great size and richness have been recognised in a belt running through the southern districts of Bihar and Orissa and constituting what is one of the most important groups of iron-ore deposits of the world.

Attempts to introduce European processes.

Earlier attempts to introduce European processes for the manufacture of pig-iron and steel, in India, had been such conspicuous failures that there was naturally some hesitation in reposing confidence in the project launched by Messrs. Tata, Sons and Company. Perhaps the earliest attempt to introduce European processes was due to the enthusiasm of Mr. Josiah Marshall Heath of the Madras Civil Service, who, having resigned the service of the East India Company, obtained the exclusive privilege of manufacturing iron on a large scale in the Madras Presidency. In 1830, trial works were erected at Porto Novo in the South Arcot district, and were maintained by subsequent financial assistance from the East India Company. The business was taken over in 1833, by the Porto Novo Steel and Iron Company, and additional works were started at Beypur on the Malabar coast. Various concessions were granted to Mr. Heath and to the succeeding iron company, but in spite of these, the undertaking proved to be a failure. In 1853, a new association, known as the East India Iron Company, was started with a capital of £400,000. This company obtained various concessions from Government, and erected two blast furnaces, one in the South Arcot district and another on the Cauvery river, in the Coimbatore district. These furnaces were stopped in 1858, whilst operations at Porto Novo ceased in 1866, and at Beypur in 1867. Other attempts to introduce European processes have been made in the Birbhum district of Bengal and at Kaladhungi in Kumaon.

Bengal Iron Company.[1]

The first scheme which proved to be a financial success is that now in operation at Kulti, near Barakar in Bengal. The Barakar iron works passed through various vicissitudes of fortune, and showed no signs of financial success until the agency was taken

[1] Information kindly furnished by Messrs. The Bengal Iron Co., Ltd.

over by Messrs. Martin & Company in 1889 when the Bengal Iron and Steel Company was formed and the plant completely remodelled. During 1919, the Company changed its title to the present form 'The Bengal Iron Company, Limited' and the change was accompanied by a substantial increase in the capital. The Kulti works have five blast furnaces, but during the period under review some of these were shut down owing to various causes. The manufacture of ferromanganese was discontinued in 1919, but in 1928, 9,032 tons of ferromanganese were produced in No. 4 furnace before the furnace was finally blown out for reconstruction.

For the last five years the pig iron output has been as follows :—

	Tons.
1924	147,733
1925	52,674
1926	20,050
1927	132,649
1928	128,112

The following are the average analyses of pig iron produced :—

— —	Grades 1, 2 and 3.	Grades 3 and 4.
	Per cent	Per cent.
Graphitic carbon	3·13	2·98
Combined carbon	0·23	0·32
Silicon	2·25	2·00
Phosphorus	1·20	1·21
Manganese	1·40	1·13
Sulphur	0·22	0·04

The blowing engines include four Parson's turbo-blowers, one of 18,000 cubic feet per minute up to 7 lbs. pressure, two of 25,000 cubic feet up to 10 lbs. pressure, and one of 50,000 cubic feet up to 10 lbs. pressure. A fifth turbo-blower of 25,000 cubic feet per minute capacity, for No. 5 furnace, was installed during the period under review, and was put into work in October, 1928.

The iron foundries cover an area of about 200,000 square feet and comprise pipe foundries, sleeper foundries, and a foundry for

general and special castings, the latter being specially equipped to deal with heavy castings. A large well equipped machine shop disposes of the works' repairs and machines the larger or more intricate castings. The bulk of the castings are, however, machined in a special shop attached to the foundry. The outturn of iron castings during the period under review was as follows :—

	Tons.
1924	27,045
1925	35,238
1926	70,818
1927	87,925
1928	47,462

The coke used is made at Kulti in four batteries, each of 34 ovens. These are all of Messrs. Simon Carves regenerative type, three being waste gas and one waste heat. The output of coke for the last five years has been as follows :—

	Tons.
1924	219,811
1925	63,407
1926	36,884
1927	138,988
1928	157,216

Tar and sulphate of ammonia are recovered from the waste gases, the necessary sulphuric acid being made also at the company's works at Kulti.

The coal supply is obtained from the company's collieries at Ramnagar some two miles from Kulti, and from the adjoining collieries of Noonodih and Jitpur in the Jharia field. The Jitpur colliery during the period under review has been developed and equipped to deal with an output of 1,000 tons per day, this being the average demand of the ironworks.

The limestone used as a flux is raw, and is obtained from the Bisra Lime Company and also from contractors at Paraghat and Baraduar on the Bengal-Nagpur railway. The average analysis of the stone is as follows :—

	Per cent.
Calcium carbonate	95 80
Silica	2·70
Ferric oxide and alumina	0·80
Magnesium carbonate	2·25

The site of the Barakar ironworks was originally chosen on account of the proximity of both coal and ore deposits. The outcrop of Ironstone shales, between the coal-bearing Barakar and Raniganj series, stretches east and west from the works, and for many years the clay ironstone nodules from this formation constituted the only supply of ore used in the blast furnaces. The use of ore from this source has been abandoned for some years in favour of the richer ore from the company's deposits in the Kolhan Estate, Singhbhum. The principal deposits are known as Pansira Buru, on which the Pansira quarries are opened up, and Buda Buru, on which the Maclellan quarries are being worked. These are situated respectively twelve and eight miles south-east of the Manharpur station of the Bengal Nagpur railway. The total quantity of ore in Pansira Buru has been estimated at 10 million tons, whilst that in the Budu Buru area is tremendous and has been roughly estimated at over 150 million tons. The ore is generally a high grade hæmatite with an average analysis of:

	Per cent
Iron	64 0
Silica	2 10
Lime	0·15
Alumina	1·25
Magnesia	0·18
Manganese oxide	0·05
Sulphur	0 002
Phosphorus	0 ·05

A 2-foot-6-inch railway line has been constructed by the Bengal Iron Company from Manharpur to Pansira, with a branch through the Ankua valley to the foot of Buda Buru. An aerial ropeway with a capacity of 40 tons hourly, transports the ore from the top of Pansira Buru (hill) to a bin at the foot, from which it is automatically loaded into the railway wagons. A gravity incline, with a capacity of 60 tons hourly, transports the ore likewise from a spur of Buda Buru to the railway at the foot. The following table shows the quantity of ore used during the period under review :—

	Iron-ore Tons.	Manganese-ore Tons.
1924	255,815	4,420
1925	48,855	2,504
1926	49,863	..
1927	220,367	5,043
1928	215,648	25,504

Labour. The average number of persons employed daily at the Kulti works was as follows:—

1924	6,245
1925	3,419
1926	3,850
1927	6,249
1928	6,735

In addition to the above, contractor's labour was estimated at 754 daily in 1924, and at 217 in 1925. During the years 1926, 1927 and 1928 there does not appear to have been any contractor's labour employed.

Indian Iron and Steel Company, Limited.[1]

The Indian Iron and Steel Co., Ld., was floated under the managing agency of Messrs. Burn & Company with a capital of Rs. 3,00,00,000 on the 11th March, 1918, for the purpose of manufacturing pig iron, by-product coke, coal tar products, sulphate of ammonia, and sulphuric acid. The company possesses its own iron-ore, coal and limestone mines, within easy reach of the works, which are situated in the fork made by the Bengal-Nagpur and the East Indian railway companies at their junction at Asansol, 132 miles north-west of Calcutta.

Blast furnace plant. The works consist of two 500-ton, mechanically charged modern furnaces. The tunnel system is employed for the handling of raw material to the furnace and 75-ton capacity ladles are used for conveying the hot metal to two double-strand pig machines or to the sand-cast pig bed. All pig iron is handled by magnets.

The blowing plant installed consists of two C. A. Parsons' high-pressure full-reaction type, steam turbo-blowers, each with an economical output of 40,000 cubic feet of free air per minute at a pressure of 14 lbs., and a maximum output of 36,000 cubic feet of free air per minute at a pressure of 23·5 lbs. Two large Parsons' turbo-blowers have also been added, each with an output of 50,000 cubic feet of air at 18 lbs. pressure, a maximum rating of 60,000 cubic feet at 23 lbs. and capable of blowing 48,000 cubic feet at a maximum pressure of 30 lbs.

[1] Information kindly furnished by Messrs. The Indian Iron & Steel Company, Limited.

Six blast furnace gas-fired Babcock and Wilcox boilers, each having 1,510 square feet of heating surface, and constructed for a working pressure of 200 lbs. per square inch, and capable of an evaporation of 75,000 lbs. of water per hour, serve the blowing plant.

Coke oven and by-product plant.

The coke oven and by-product plant consists of two batteries, each of eighty Simon-Carves, horizontal-flue, waste-heat ovens capable of producing 1,000 tons of coke per day. A battery of forty Simon-Carves, underjet ovens, capable of producing 450 tons of coke per day, has also just been put into operation. The coal-charging cars and the combined leveller and coke rams employed are electrically driven. The coke is discharged on to inclined coke cars which are hauled by electric locomotives to central quenching stations. When quenched, the coke is discharged on to an inclined coke bench and fed by means of a belt conveyor over a screening plant and discharged direct into the blast furnace bunkers.

The direct recovery system is employed for the recovery of by-products, and a sulphuric acid plant capable of producing 18 tons of 80 per cent. acid per day from natural sulphur has been installed.

Electric power plant.

Two 3,000 K. W. turbo alternator sets, with the Westinghouse Rateau high-pressure type of turbine, driving the Westinghouse alternating current type of generator, are in operation and an auxiliary 150 K. W. direct current lighting set has also been installed to provide for works and bungalow lighting, should the large sets not be running. The necessary steam for driving the turbines is obtained from a battery of ten Babcock and Wilcox patent water tube boilers arranged for firing with waste heat from the coke ovens and with surplus gas. Each boiler has a heating surface of 5,246 square feet and is constructed for a working pressure of 200 lbs. per square inch.

Water supply.

The necessary circulating water for the turbo-blowers, turbo-alternator, blast furnace plant and the works is obtained from a large reservoir on the works area containing approximately 300,000,000 gallons of water; the make-up water for the reservoir is pumped from the Damodar river at a distance of $2\frac{1}{2}$ miles from the works by two electric pumps, each capable of pumping 60,000 gallons per hour.

The whole of the above-mentioned plant is in full operation and a ready market is being found for all the company's products.

The company's ore mines are situated at Gua in the Kolhan Government Estate, Singhbhum. The Bengal-Nagpur railway have a branch line terminating at Gua which is fully capable of taking all the ore from these mines. The mines are now almost fully developed, and are capable of an output of over 60,000 tons per month.

Ore mines.

A ropeway having a capacity of 120 tons per hour has now been in use some years, and is giving every satisfaction. Feeding into the bunker at the top of the ropeway, are two self acting inclines, one being on the endless rope principle. The ordinary two-ton mine tubs are clipped to the rope at intervals, the descending loads drawing the empty tubs up. The speed is controlled by brakes. An output of 800 tons daily is obtained from this incline. The second incline is operated by eight-ton skips. On this incline the gradients are very severe, and the brakedrums are controlled by eight double post brakes. The output from this incline will eventually be 1,000 tons daily. A third incline is being made similar to the second one. The output from here will be from 600- 800 tons daily when it is working at the end of 1930.

At the bottom of the ropeway the buckets are emptied into a 2,000-ton capacity bunker. The hopper wagons supplied by the railway are loaded direct from this bunker at the rate of 10 tons per minute.

An endless rope self acting incline $1\frac{1}{2}$ miles long bringing ore from the mines 2,800 ft. above sea level down to the railway at 1,480 ft. was started in February, 1929. The tubs from this incline are emptied into a crusher by means of a power driven tippler, the tubs being returned to the incline by means of an automatic traverser. The ore is reduced to 2-inch cube size and then emptied direct into the hopper wagons. When fully developed the output from this incline is expected to be 800 tons daily.

In the Jhilling Buru area a light railway brings ore mined from the reef at the lower level, the tubs being emptied direct into the wagons. There is also an incline operating with skips bringing ore from the top of the hill. The ore is brought by means of a light railway from the quarries to the bunker at the top of the incline. It is then loaded into a skip, which on arrival at the bottom of the incline is emptied into a crusher, the ore is reduced to $2\frac{1}{2}$-inch cube. The output from this area is expected to be 1,000 tons daily.

The power plant at present consists of a 250 K. W. generator. This drives the various compressors and pumps on the mines. A

new power house is at present being built. The new 625 K. W. Parsons turbo-generator is already at the mines, and the plant will be running in a few months' time. A second turbine will probably be put in later. Nearly all drilling on the mines is done by Jack-hammers, driven by means of one steam, and two electrically driven compressors.

A large labour force have been induced to live on the mines, where suitable accommodation has been provided. The drinking water for the labour, and the feed water for the locomotives on the ropeway section is supplied by means of a 7,000-gallon per hour turbo-pump, pumping up from springs in the valley 1,000 ft. below. Another spring on the other side of the hill supplies water to the village.

Tata Iron and Steel Company.[1]

The Tata Iron & Steel Company possesses rich iron-ore deposits in the Drug district, Central Provinces, in the Kolhan Government Estate of the Singhbhum district, Bihar and Orissa, and in Keonjhar State, but prior to 1926 (when Noamundi iron mine in the Kolhan was opened) practically the whole of the supplies of iron-ore came from their deposits in Mayurbhanj State, which are nearest to the site of the works and to which the Bengal-Nagpur Railway Company has built a branch line about 56 miles in length.

Iron-ores of Mayurbhanj State.

The occurrence of valuable iron-ore deposits in Mayurbhanj was first noticed by P. N. Bose, who mentioned the following occurrences :—

(*a*) Bamanghatti sub-division :—
- (1) Gurumahisani Hill, over an area of 8 square miles.
- (2) Near Bandgaon in Saranda-pir.
- (3) Sulaipat-Badampahar range from Kondadera to Jaidhanposi, a distance of some 12 miles.

(*b*) Panchpir sub-division :—
At several places from Kamdabedi and Kantikna to Thakurmunda, a distance of 25 miles.

(c) Mayurbhanj proper :—
Simlipahar range, and the submontane tract to the east (Gurguria, Kendua and Baldia).

[1] Information kindly furnished by Messrs. The Tata Iron & Steel Company, Limited.

Subsequently, on the possibility of these ores being suitable for the proposed iron and steel works, they were re-examined by Messrs. C. P. Perin and C. M. Weld, who arranged for detailed prospecting operations after securing prospecting rights from the Maharajah. A subsequent examination of the ground by Mr. W. Selkirk having demonstrated the existence of sufficient ore to warrant operations on a large scale, a lease was granted to the company over 12 square miles.

Prospecting operations determined the existence of over a dozen considerable deposits of high-grade ore in the more accessible parts of the state (see fig. 10). Of these deposits three, namely; Guru-

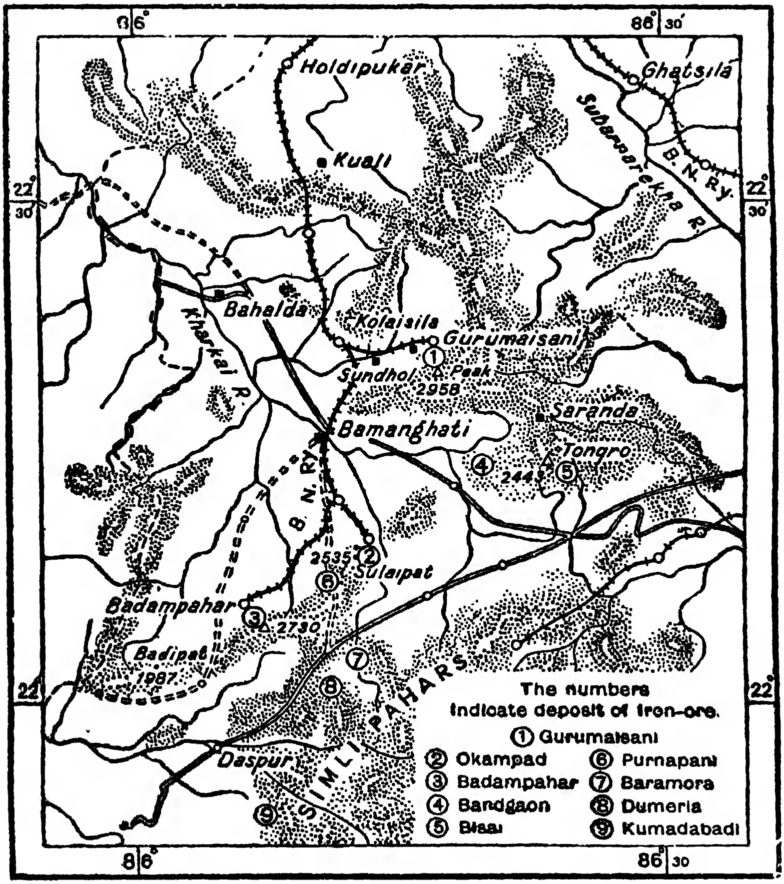

FIG. 10.—Map showing position of the Mayurbhanj iron-ore deposits
Scale 1 inch=16 miles.

mahisani, Okampad (Sulaipat), and Badampahar, so far overshadow the others that reference will be made in detail to them alone. The ores are of the same type as those of Singhbhum and Orissa described by Mr. H. Cecil Jones[1]. The 'hæmatite breccia' mentioned by Mr. Jones is rare in the Mayurbhanj deposits, but the other types are all present, including the shaly laminated ore and the powdery 'micaceous hæmatite.' Deposits of these two types have recently been exposed *in situ* in the workings at Gurumahisani. Magnetite, which has not been reported in the South Singhbhum deposits, is found at Sulaipat and Badampahar.

Interbedded with the ores are quartzites and shales, and the former are often closely interbanded with hæmatite, the thickness of the alternating bands of quartz and hæmatite varying from about a quarter of an inch down to a mere streak. The hæmatite in this 'banded-hæmatite-quartzite' is not perfectly regular. It thickens or thins out, transgressing across the bands or filling up small fault fissures in the quartzite.

(1) Gurumahisani.

The Gurumahisani hill-mass, with its three prominent peaks, the highest rising to an elevation of 3,000 feet above sea level, and its numerous flanks and spurs, forms a conspicuous feature in the topography of the northern part of the state. The large quantity of iron-ore found at this point and its accessible position combined to make it the first point of attack. In 1914-15 a careful estimate of the contents of the Mayurbhanj deposits was made by Mr. E. Curnow, and Gurumahisani was proved to contain 9,800,000 tons of ore. Since that date about 5 million tons have been extracted, but the recently exposed *in situ* deposits of shaly laminated ore above mentioned, which were concealed under a heavy thickness of 'float' ore, suggest the possibility of further discoveries that may increase the estimated reserves by two or three million tons.

Up to the end of 1928, the whole of the ore won at Gurumahisani was float ore. The first deposits *in situ* to be worked were reached only in the early part of 1929. The lower slopes of the hill have now been worked out and practically no ore remains below a height of about 250 feet above the plain level.

The average iron content of the ore despatched from Gurumahisani at the present time is about 64 per cent.

[1] *Rec. Geol. Surv. Ind.*, LIV, pp. 203-214 (1923).

The following analyses of samples taken in the course of the several examinations to which the deposits have been subjected are of interest :—

——	Iron.	Phosphorus.	Sulphur.	Silica.
	Per cent.	Per cent.	Per cent.	Per cent.
Average of eleven samples both 'solid' and 'float' ore.	61·85	0·135	0 036	4·08
Average of 20 samples of 'float' ore.	61·46	0 048	0·036	3·34
Average of ten samples of 'solid' ore.	64·33	0·075	0 021	1·64

A number of these samples were put through a complete analysis whereby were proved the absence of titanium, chromium, zinc, nickel, cobalt (except in one case where 0·090 per cent. was found), copper, lead and baryta, and the presence of arsenic in traces only (in one case up to 0·008 per cent.).

(2) Sulaipat.

The Sulaipat (or Okampad) ore deposit is situated just west of the Khorkai river, where the latter breaks through the Sulaipat-Badampahar range. Okampad is a conspicuous peak, only slightly lower than the Sulaipat peak (2,535 feet elevation) which lies one mile to the south-west of the former. Gurumahisani lies 12 miles to the north-north-east. Sulaipat ore is very rich, and a certain amount of it is magnetite. It is despatched in two grades: -that for open hearth furnace use runs from 67 to 69 per cent. Fe., whilst the blast furnace quality ore yields about 65 per cent. Fe., whilst representative samples give on analysis :—

	Per cent.
Fe	65·20
Mn	0·14
SiO_2	4·76
Al_2O_3	0·510
P	0·036

An extension of the Gurumahisani railway was completed in 1922, to Badampahar and a narrow gauge tram-line four miles long has been built from the Sulaipat mine to a loading siding on this extension.

The main ore-body occurs on the top of the hill, exhibiting at one point a scarp some 200 feet high and covering a superficial area of about 56,400 square feet in plan. A small outlier lies to the west of this, and these two ore-bodies were estimated by Mr. Curnow to contain some 2,270,000 tons of ore. The 'float' at Sulaipat is very rich and was estimated at 936,000 tons, making a total of 3,206,000 tons for this deposit.

Recently the removal of float ore has revealed certain bands of ore *in situ* that were not visible at the surface. These have not yet been investigated in detail.

The intimate associates of the ore are banded hæmatite quartzite, and a very abundant fine-grained blackish quartzite superficially resembling first grade ore. The surrounding low-lying area is occupied by granite and both the rocks of the hill and the granite are cut by a network of dolerite dykes.

(3) Badampahar.

The last of the three major deposits occupies the Badampahar peak (2,706 feet elevation) in the Sulaipat-Badampahar range, 8½ miles south-west from the Sulaipat ore-body. All the workings up to the present have been confined to the float ore, which is, however, not so continuous here as at Gurumahisani. The source of the 'float' is a series of small ore-bodies capping the crests of the main hill and the spurs. The absence of continuity in these deposits is probably mainly due to faulting, but there are several quite distinct types of ore at Badampahar and the relationships of the various ore-bodies are not yet worked out. The total amount of ore at Badampahar was estimated by Mr. Curnow at 8,800,000 tons, but later work suggests that probably 7 million tons is a more accurate figure.

One very peculiar yellow ore, very light in weight and so poor in appearance, that for a long time it was ignored without analysis, yielded results in certain cases as high as the following, and is now being regularly railed :—

	Per cent.
SiO_2	0·72
Al_2O_3	0·42
Fe	66·60
Mn	trace
P	0·062
S	0·15
TiO_2	*nil*
Combined H_2O	2·40

The yellow colour is apparently due to the presence of limonite but this ore in general appears to be derived from the replacement of a dolerite sill. One of the tramway cuttings has exposed an altered dolerite rock in which the percentage of iron varies from 26 to 37 per cent., and possibly it may prove to pass laterally into material sufficiently enriched to be worked as ore.

One o the deposits at Badampahar is magnetite. This is a small isolated solid ore-body and is in the neighbourhood of a peridotite dyke, with which it may be genetically connected. The bulk of the ore, however, is hæmatite of similar type to that of Gurumahisani but not so rich.

Most of the Badampahar ore is more porous than either Gurumahisani or Sulaipat and is highly regarded on that account in spite of its lower iron content. The ore as despatched averages about 57 per cent. to 58 per cent. Fe., a representative sample giving on analysis :—

	Per cent.
Fe	57·60
Mn	0·52
SiO_2	5·60
Al_2O_3	5·02
P	0·074

Iron-ores of the Kolhan, Noamundi.

Noamundi iron mine is in the Kolhan Government Estate in the Singhbhum district. The ore occurs in thick bedded deposits of hæmatite averaging well over 60 per cent. of iron. If selected material were needed there would be no difficulty in maintaining despatches averaging over 67 per cent. of iron. The ore is found on two main parallel ridges rising to a maximum height of about 1,000 feet above the railway level. It has a variable westerly dip, and is widely exposed on the dip slopes. It is considerably faulted in the northern part of the mine, but less so to the south. The sequence is as follows :—

4. Upper ore beds
3. Banded hæmatite quartzite
2. Lower ore beds
1. Pink and white shales.

The two ore horizons are very much alike. The ore at the surface is either hard and massive or laminated, but in the latter case it may be soft and shaly in appearance. It is often lateritised to consider-

able depths. Below 100 feet in depth it appears to be mainly powdery ore ('micaceous hæmatite' or 'blue dust'), but in places it passes into powdery ore at quite shallow depths.

The mine is connected with the Bengal-Nagpur Railway Company's Amda-Gua extension by a broad gauge siding from Noamundi station. Despatches commenced in 1926, and the bulk of the ore despatched up to date is of the softer laminated type, averaging about 62·5 per cent. iron content, with about 3·75 per cent. silica and 3 per cent. alumina.

The following table summarises the tonnages despatched from all four mines during the period under review :—

——	Gurumahisani.	Sulaipat.	Badampahar.	Noamundi.	Total.
	Tons.	Tons.	Tons.	Tons.	Tons.
1924 . .	422,798	140,287	339,319	..	902,404
1925 . .	472,657	143,041	317,916	..	933,614
1926 . .	486,910	158,155	370,987	170,594	1,186,646
1927 . .	499,533	86,326	168,363	480,420	1,234,642
1928 . .	408,139	32,287	49,398	379,620	869,444

The reduced despatches from Sulaipat and Badampahar in 1927, were due to the destruction of the Bengal-Nagpur railway bridge at Rairangpur by floods at the end of July, 1927, whilst the general reduction at all mines in 1928, was on account of a strike at the works at Jamshedpur.

Messrs. Bird and Company.(a)

During the period under review, Messrs. Bird and Company have commenced exporting iron-ore from the Keonjhar state. The whole of the iron-ore output at present is being sold to Messrs. Burn and Company for use in the Indian Iron and Steel Company's blast furnaces at Burnpur. The iron-ore is quarried in the Bagia Buru ridge, north-west of Barabil village. The ridge runs parallel to the branch line of Bara Jamda-Barabil branch of the Bengal Nagpur railway. The workings lie partly in the Khendra and partly in the Barabil lease areas, and are entirely within the Keonjhar state. The ore is hæmatite and contains 58 to 60 per cent. iron,

(a) Information kindly furnished by Messrs. Bird and Company.

with practically no manganese. The iron-ore being mined is partly solid-bedded ore and partly the float ore surrounding the outcrops and derived from the former.

The third grade manganese ore usually referred to by Messrs. Bird and Company as 'manganiferous iron ore', and obtained during the manganese mining and dressing operations in the same area, is also sold to the same company for blast furnace additions to give the required manganese content to the pig-iron. The ore runs between 30 and 35 per cent. manganese and about 20 per cent. iron, the latter being present in the form of limonite.

The output during the last five years has been as follows:—

	Iron-ore. Tons.	Manganiferous iron-ore. Tons.	
			includes
1924	..	4,881	(115 Singhbhum)
1925	148	11,302	(21 ")
1926	231	9,796	(*nil*)
1927	36,325	13,397	(*nil*)
1928	141,361	17,122	(657 Singhbhum)

A very small amount of manganiferous iron-ore, as indicated above, was obtained from a number of detached plots within two or three miles of Bara Jamda station in Singhbhum.

Iron-ores of Singhbhum, Keonjhar and Bonai.

This most important iron-ore area in India, now being developed by the above-mentioned companies, is situated some 150 to 200 miles to the west of Calcutta in the province of Bihar and Orissa and contains extremely large and rich deposits of iron-ore. They occur in the Kolhan Government Estate in the Singhbhum district, and in the feudatory states of Keonjhar, Bonai, and Mayurbhanj. The deposits in the areas examined are remarkable for the enormous quantities of extremely rich ore they contain, and will undoubtedly prove to be amongst the largest and richest in the world. In the last review it was stated that iron-ore was reported to occur in the feudatory state of Pal Lahara. This occurrence has since been examined, and the material is much too siliceous to be of any economic value at the present time.

The iron-ore usually occurs at or near the tops of hills or ranges of hills, but near Jamda in the south of the Singhbhum district, and in parts of the Keonjhar state it is often found at very low

levels, and in some cases actually in the plains themselves. The most important of these ranges of hills is the one that starts near Kompilai in the Bonai state, and continues to the N. N. E. to a point above three miles south-west of Gua, a distance of about thirty miles. Running more or less parallel to this range, and possibly faulted from it, are other smaller ranges which contain good iron-ore. The main range rises some 1,500 feet above the plain, and iron-ore averaging over 60 per cent. of iron occurs for practically the whole length of the thirty miles. A few small breaks occur, where the rock has not been replaced or where folding has occurred, but these are negligible compared with the total length. The rocks forming this range dip at about 70° in a direction between north-west and west.

To the east and west of these ranges, again, are more irregular patches of ore occupying the tops of hills. Large quantities of float and brecciated ore usually occur with the ore-bodies.

Mineralogy and nature of the ores.

Practically the whole of the ore is hæmatite and as far as is known no quantity of magnetite occurs in the ore-bodies. Small octahedral crystals occur in the ore occasionally; some are magnetite but they appear to be mainly martite,[1] as the rock generally has no appreciable effect on the magnetic needle. Small octahedral crystals, some of which are magnetite and some of which appear to be martite, occur also in the banded hæmatite-quartzite. The hæmatite is rather variable in character and the varieties may be grouped as follows:—

(1) Massive hæmatite.
(2) Laminated hæmatite.
(3) Micaceous hæmatite.
(4) Lateritic hæmatite.
(5) Hæmatite breccia.

The Kolhan hæmatites usually appear to contain about 64 per cent. of iron, with phosphorus ranging from 0·03 to 0·08, or in some cases, to as high as 0·15 per cent. The sulphur content is usually below 0·03 per cent. Titanium in very small quantities is also said to be found occasionally in the ore. Samples from the better parts of the ore-deposits contain as much as 68 or 69 per cent. iron.

[1] Registered No. L. 584, in the Geological Survey of India's collections.

The main points of numerous analyses of these ores are the high iron content, the low percentage of sulphur and titanium, and the variability of the phosphorus content. Manganese in any quantity seems to occur only in the lateritic variety of the ore.

Distribution and quantity of ore.

The major part of the iron-ore seems to be fairly evenly divided between the Singhbhum district, the Keonjhar state and the Bonai state. The minimum quantities estimated up to the present for ore averaging not less than 60 per cent. of iron are—

	Tons.
Singhbhum district	1,074,000,000
Keonjhar State	806,000,000
Bonai State	656,000,000
Doubtful, Bonai State or Keonjhar State	280,000,000
Mayurbhanj State	16,000,000 (?)
TOTAL	2,832,000,000

The reported estimate of the quantities of ore in the Mayurbhanj state has not yet been verified, but recent discoveries of *in situ* ore, seem to indicate that this estimate of 16,000,000 tons will be considerably increased.

The prospecting work and mining operations, carried out by the various companies, indicate that the solid hæmatite often gives place to an unconsolidated micaceous powdery variety at varying depths of from 80 to 100 feet below the surface.

Geology.

The rocks of the Singhbhum iron-ore area are shown by Maclaren [1] in his account of 'The Auriferous occurrences of Chota Nagpur, Bengal', as Dharwars. The metamorphism is, however, very much less than one expects to find in Dharwar rocks and the writer of this article found undoubted proof near Jaganathpur, south of Chaibassa, that the Iron Ore series rests unconformably on upturned schists and quartzites of a typical Dharwar facies.

The lower beds of this younger group in South Singhbhum consist of sandstones, limestones and shales, of typical sedimentary aspect and almost unmetamorphosed and were in the early stages of the iron-ore area survey considered to be of post-Dharwar age.[2]

[1] *Rec. Geol. Surv. Ind.*, XXXI, p. 70 (1904).
[2] *Mem. Geol. Surv. Ind.*, LIV, p. 153 (1929).

Dr. Dunn, however, has traced these almost unaltered sediments into North Singhbhum and has stated that they take on a gradually increasing metamorphic character both along the strike and across the dip, until to the north and west of Chakardharpur the rocks become typical metamorphic schists whose lithological characters are identical with those of the older metamorphics. He states that the Iron Ore series should be considered as part of the Dharwar system. The result of this work is that these rocks of South Singhbhum have been classified as 'Older Dharwars' overlain unconformably by the 'Iron Ore series' or 'Newer Dharwars'.

The Dharwar schists and quartzites are certainly the oldest rocks recognised in the area, and after their uplift and denudation, the rocks of the Iron Ore series were laid down on them unconformably. A mass of granite was then intruded into the whole, but it seems to have raised and folded the Iron Ore series rather than to have penetrated them to any large extent. This was followed by a period of basic intrusions, which took the form of dykes in the granite area, and to a less extent in the Iron Ore series. There are also large quantities of interbanded basic igneous rocks in the Iron Ore series, some of which appear to be contemporaneous with and some later than the series itself. Some ash beds have been found in the interbanded igneous rock. These intrusions of igneous material were accompanied or followed shortly after by folding and faulting of the Iron Ore series on a very extensive scale.

Intrusions of ultra-basic rocks into the Iron Ore series and possibly into the granite also occur.

The Lower Dharwar rocks consist mainly of quartzites with hornblende, quartz and mica-schists; the strike and dip are variable.

The Iron Ore series commences with a basal sandy conglomerate which passes up into a purple sandstone, ranging in thickness up to about 60 feet, and in places very coarse-grained; the conglomerate consists of angular and rounded pebbles of red jasper and white quartz cemented together by purple sandy material. The conglomerate is not always present and bands of similar conglomerate occur at different horizons in the sandstone. This conglomerate and sandstone is overlain by about 40 feet of purple and pale greyish limestone, which contains a considerable amount of fine-grained chloritic material along the bedding planes. This in its turn is overlain by a great thickness of shales, which are often very ferruginous and penetrated by thin veins of quartz. Above these shales come banded hæmatite-quartzites

comprising bands up to about an inch in thickness of hæmatite, chert and jasper in varying proportions. In places the hæmatite-quartzites are seen to pass along the strike into good ore. Above the hæmatite-quartzites is another thick group of shales, which is also often very ferruginous. Both groups of shales contain small lenticular beds of sandstone. The hæmatite occurs as a replacement product in the banded hæmatite-quartzite, and to a much less extent in the shales above and below the quartzite.

The rocks of the Iron Ore series near the granite south of Chaibassa have a general N. N. E. to S. S. W. strike and are gently folded. Towards the west the dips become greater, and the rocks have been very much folded and faulted. This faulting is well seen near Lipunga, and a strike fault apparently runs along the east side of the main iron-ore range. The rocks to the west of the fault have a very steep dip in a westerly direction. In the north part of the range the banded hæmatite-quartzites and the hæmatites have a general N. N. E.—S. S. W. strike, and dip at about 70° W. N. W.; but towards the south the strike becomes nearly N.—S. with a similar dip to the west.

Iron-ores of the Drug district, Central Provinces.

The occurrence of valuable iron-ores in the Raipur district was not appreciated before Mr. P. N. Bose briefly referred to the chief deposits.[1] The district having been explored again on behalf of Messrs. Tata Sons and Company by Mr. C. M. Weld, a large area in the Dondi-Lohara *zamindari*[2] in the western part of the district was taken up under prospecting license for detailed examination. The iron-ores, on account of their resistance to weathering agents, stand up as conspicuous hillocks in the general peneplain. The most striking of these is the ridge, which includes the Dhali and Rajhara hills, extending for some 20 miles in an almost continuous zigzag line, and sometimes rising to heights of 400 feet above the general level of the flat country around. The iron ores are associated with phyllites and are often of the usual type of banded quartz-iron-ore schists characteristic of the Dharwar system. But in places thick masses, apparently lenticular in shape, are formed of comparatively pure hæmatite, and one of these in the Rajhara hills has been subjected to very careful examination by diamond drilling.

[1] *Rec. Geol. Surv. Ind.*, XX, p. 671 (1887).

[2] This portion of the Raipur district has been included in the new district of Drug formed in 1906.

The Rajhara mass was carefully sampled across the surface at each point selected for a drill hole and the cores obtained were also analysed in lengths representing successive depths of 10 feet each from the surface, giving altogether 64 samples which were assayed for iron, phosphorus, sulphur, silica, and manganese. The average results obtained for the surface samples were as follows:—Fe., 66·35; P., 0·058; S., 0·108; SiO_2., 1·44; Mn., 0·151, per cent.; while for the cores the averages were:—Fe., 68.56; P., 0·064; S., 0·071; SiO_2., 0·71; Mn., 0·175, per cent. In this Rajhara mass the prospecting operations thus proved the existence of 7½ million tons of ore carrying about 67·5 per cent. of iron and a phosphorus content only slightly below the Bessemer limit. The quantity estimated is that which may be regarded as ore in sight, while it is almost certain that much larger quantities may be obtained by continuation of the ore-bodies beyond their proved depth. There are other large bodies of ore in this area which have not been examined in the same detail. These masses of hæmatite include small quantities of magnetite, but separate determinations of the iron in the ferric state have not been made in order to determine the relative proportions of the two minerals.

Iron-ores of the Chanda district, Central Provinces.

The Lohara hill ore-mass has been known for a long time and was described by T. W. Hughes in 1873, who stated that the iron-ore forms a hill three-eighths of a mile in length, 200 yards in breadth and 120 feet in height. It is reputed to contain at least 2 million tons of good quality hæmatite. Average Lohara ore is said to contain 61 to 67 per cent. iron, 1·5 to 11 per cent. silica, 0·012 per cent. sulphur, and 0·005 per cent. phosphorus.

Iron-ores of the Jubbulpore district, Central Provinces.

In addition to the results of prospecting operations conducted for the Tata Iron and Steel Company in Mayurbhanj and the Central Provinces, valuable information has been collected by Mr. E. P. Martin and Professor H. Louis in the Jubbulpore district. Prospecting operations conducted in this area showed that while iron-ore is widely distributed and the formations in which it occurs are prominent in the district, there are no rich ore bodies of large size that could be relied on for the output necessary to maintain an important industry, and most of the ore, being in the form of soft micaceous hæmatite, would be physically unfit for use in a blast furnace. Generally, also, the ores in this district contain a proportion of phosphorus too high for acid Bessemer steel.

Mysore.

Iron-ores are known to occur in large quantities in the Mysore state, and have been investigated by the Mysore Geological Department. We are indebted to Dr. W. F. Smeeth for the following notes:—

The ores appear to belong to various phases of the Archæan complex and to differ considerably in their modes of origin. The hæmatite ores of the Bababudan hills are by far the most abundant and are of good quality but vary considerably in the amount of phosphorus they contain. The following classification seems to be in accordance with the numerous observations so far recorded:—

(1) Banded ferruginous-quartz rock which occurs as a common integral component of the Dharwar schists. The banded ferruginous-quartzites are very widely distributed and vary greatly in the respective proportions of magnetite and hæmatite present. A number of samples from the scarps of the Bababudan hills gave averages of 38 per cent. and 42 per cent. of iron, but many of the outcrops contain less. Owing to the very intimate admixture of the quartz and iron-ore grains in these rocks magnetic concentration has not proved very successful. Fine crushing is necessary but even after crushing through 60 mesh the richer concentrate (Fe, 64 per cent.) contained only 25 per cent. of the iron in the rock. With a stronger magnetic field between 60 and 70 per cent. of the iron can be recovered in a concentrate assaying about 60 per cent. Fe. The following analyses represent averages of a large number of samples divided for convenience into three grades. The analyses are made on dried ores, the moisture being usually under 1 per cent.

——	High grade.	Medium grade.	Low grade.
	Per cent.	Per cent.	Per cent.
Loss on ignition	5·23	8·87	10·61
SiO_2	1·12	1·96	3·62
Al_2O_3	2·36	3·60	9·42
TiO_2	trace	trace	0·20
Mn	0·10	0·13	trace
Fe	64·24	58·66	53·85
S	0·038	0·038	0·03
P	0·031	0·038	0·05

(2) Desilicified portions of (1) with, in some cases, addition of iron from solution or by metasomatic replacement of quartz and silicates. These form rich hæmatite and limonite ores. The banded ferruginous-quart-

zites are usually steeply inclined, but sometimes lie nearly horizontal. This latter is the case over the eastern portion of the Bababudan hills, where these rocks form an undulating capping of from 200 to 500 feet in thickness on top of the green-stones and hornblende schists at an elevation of about 5,000 feet. In this area the banded quartzites outcrop where there are sharp local folds or crumples, or where there has been much denudation. On the more gentle dips and undulations, solution of the silica has been active and has caused the removal of the quartz to a depth of many feet. The result is the production of a more or less banded and porous layer of hæmatite ore to a variable depth—in places 10 feet and probably deeper. A sample taken to a depth of 9 feet gave the following analysis :—

Moisture at 100° C.—0·36 per cent.

Ore dried at 100°C.

H_2O	6·00	Fe	58·37
Fe_2O_3	82·79	P	0·057
FeO	0·54	S	0·047
MnO	0·08		
Al_2O_3	9·82		
MgO . . .	0·26		
CaO	0·13		
SiO_2	0·77		
P_2O_5	0·13		
SO_3	0·118		
	106·38		

(3) Zones or layers of massive ore,—probably the result of the metasomatic replacement of silicates (igneous and metamorphic schists) by oxides of iron. These are either limonites or hæmatites and are sometimes associated with (1) and sometimes not. In some places they are associated with manganese-ores. Such ore-bodies have been found amongst the steeply inclined schists of the Shimoga district and also in the Chitaldroog schist belt, in both cases near or adjacent to manganese-ores. As regards quantity, there can be no doubt that a very large supply of fairly good ore can be obtained from various points on the eastern section of the Bababudan hills, but no satisfactory estimate would be possible without extensive prospecting. Of ores containing about 64 per cent. iron a few million tons could probably be obtained, but it is questionable whether it would be worth while to pick such a high grade in iron. Of ores running about 60 per cent. iron probably some 25 to 50 million tons could be obtained in several large deposits, and of lower grade ores, down to 55 per cent. iron, the quantity might safely be put at 100 millions and probably at several times this amount.

(4) Magnetite and hæmatite lenses which appear to be of magmatic origin associated with ultra-basic rocks intrusive into the Dharwar schists. They are usually highly titaniferous.

A number of long lenticular outcrops of these iron-ores have been found in the Channagiri *taluk*. The ores from a large number of outcrops have a strong family resemblance, and of the more massive varieties several hundred thousand tons are easily available. Partial analysis of a number of samples showed that the ores were all very similar, and a more complete analysis of one gave the following:—

	Per cent.
H_2O (total)	1·23
SiO_2	0·83
Fe	56·82
S	0·049
P	*nil*
MnO	0·48
Cr_2O_3	3·09
Al_2O_3	1·79
CaO	0·72
MgO	1·58
TiO_2	11·60

The large amount of titanum spoils these ores for smelting purposes. The absence of phosphorus and the presence of chromium are features of all the samples. Some ores of this series also occur in the Nuggihalli schist belt of the Channarayapatna *taluk*, where they are closely associated with chrome ores in a series of amphibolites and peridotites.

(5) Quartz-magnetite ores, which appear to be of magmatic origin and genetically related to the charnockite series and therefore subsequent to the Dharwar schists and to the Archæan gneiss. These ores occur in the Malvalli *taluk*, north of the Cauvery river, where the charnockite masses of Kollegal penetrate the older gneiss and schists in tongues and dyke-like intrusions. They are found also in parts of the Mysore district.

Numerous gradations have been observed between the normal basic charnockite and these ores, in which we get increases in the proportion of the magnetite and quartz with diminution of the felspar and ferro-magnesian constituents, and finally a rock composed essentially of quartz and magnetite with a little accessory hypersthene, amphibole, or garnet. The rock occurs in long thin lenses or dykes in the more normal charnockites or in the older gneissic complex, and the constituent minerals are usually grannular without any marked tendency to a banded arrangement.

The State iron industry on modern lines.

The results of preliminary investigations carried on by the Mysore Geological Department regarding the feasibility of the manufacture of pig-iron from the iron-ore deposits of the Bababudan hills, Kadur district, and some other subsidiary deposits in the adjoining Shimoga district having been favourable, the Government of Mysore consulted Mr. C. P. Perin, the technical expert, in 1915, to formulate for them a workable scheme for smelting the ores in

charcoal furnaces. On his recommendations, the Government decided in 1918, to start the industry under the title of the 'Mysore Iron Works' at Bhadravati, 11 miles east of Shimoga. Owing to unforeseen and unavoidable delays in getting the necessary material and setting up the plant, smelting operations could not be started before 1923.

The works are located at Bhadravati, on the Birur-Shimoga branch line of the Mysore state railway, which is about 11 miles east of the town of Shimoga, and is situated on the west bank of the river Bhadra. A new town laid out on modern principles has been built close to the works for the use of its employees. All the sections are at present under the charge of Indians, who are mostly natives of Mysore. The management is subject to the control of a board of directors and a chairman.

The raw materials are transported to the works by lines of tramways, and the Birur-Shimoga meter-gauge railway. The length of tramlines laid out at present is 60 miles.

The main source of ore supply is the Kemmangundi ore-field, which is about 2½ miles north-west of the Kalhatti bungalow on the top of the Bababudan hills and about 26 miles south of Bhadravati. The ore is mostly hæmatite with some limonite, and is mined in open quarries. The ore from different working-spots is trollied and collected in a bin placed at the upper terminal of the ropeway whence it is fed into buckets, handed down the ropeway and dumped automatically into the open bin at the lower terminal. From here it is railed to Bhadravati. The ropeway is about 3 miles long and the vertical drop from the upper terminal at Kemmangundi to the railhead at Tanigebail is 2,000 feet. Its capacity is about 300 tons per day, and it was completed in 1924.

It was first proposed to bring the dolomite flux from a quarry at Voblapur in the Tumkur district, but the cost of transport being heavy, the proposal was given up, suitable material being obtained from the newly opened quarry on the Shankargudda range of hills in the Shimoga district which could be supplied to the works at less cost. Limestone is now used as flux and is obtained from Bhandigudda (Bhadigund) near Gangur which is about 13½ miles east of Bhadravati.

The siliceous ore required for mixing with the iron ore is obtained from a quarry opened up about 3 miles west of Birur; it is railed to the works at Bhadravati.

Owing to the delay experienced in completing the construction of the aerial ropeway down the slopes of the Bababudan hills and to other difficulties, the first supplies of iron-ore were got from a subsidiary deposit, which is entirely limonitic, at Chattanhalli, whence they were readily conveyed to the works by the tram and rail lines of the United Steel Co., and the Mysore railway. Work was stopped at Chattanhalli after the completion of the ropeway.

The average analyses of ores and fluxes put into the smelting furnace at present are as follow :—

——	Kommangundi iron-ore.	Limestone.	Siliceous iron-ore.
	Per cent.	Per cent.	Per cent.
Loss on ignition	7·50	40·33	0·64
SiO_2	2·00	5·17	58·85
Al_2O_3	4·00	1·00	0·75
Fe_2O_3	85·71	1·25	37·93
TiO_2	trace	*nil*	*nil*
MnO	trace.	0·79	1·00
CaO	*nil*	48·67	0·50
MgO	*nil*	2·23	0·28
P_2O_5	0·14	*nil*	0·045
SO_3	0·075	*nil*	0·042

The wood required for making charcoal by distillation comes entirely from jungle trees, which cannot be made use of for any better purpose; it is being supplied from coupes which have been systematically laid out and worked in the State forests adjoining the works.

The works comprise smelting plant and the wood distillation with its by-product recovery plant. At present there is installed a single blast-furnace of the American type with complete equipment, and it has a capacity of about 60 tons of pig-iron per day. The distillation plant comprises a set of ovens for burning wood in closed chambers and converting it into charcoal, and a system of pipes and apparatus designed for the recovery of the by-pro-

ducts—wood-alcohol, acetate of lime and wood-tar. After five years of construction, production work was commenced in the month of January, 1923. The daily output of pig-iron has gradually risen from 40 to 45 tons per day to the maximum capacity of 60 to 65 tons per day.

The annual output of the ores and fluxes in tons for the calendar years 1924-1928 are :—

Year.	Kommangundi iron-ore.	Limestone.	Siliceous iron-ore.
1924	6,892	..	2,696
1925	56,218	8,003	..
1926	15,462	3,956	1,909
1927	45,389	..	2,031
1928	21,460	..	1,291

The large tonnage in 1925 was due to a large portionof the mining work for the season 1925-26, having been done during the latter part of 1925, owing to a large influx of labour at that time.

The output of pig-iron during the five years has been :—

	Tons.
1924	16,425
1925	16,741
1926	19,523
1927	19,858
1928	15,104

The results of analyses of this pig-iron show :—

Si	0·2	to	3·5	per cent.
Mn	0·2	to	2·5	„
C (total)	3·5	to	4·8	„
P	0·06	to	0·15	„
Cr.	0·02	to	0·03	„
S	0·02			„
Fe	92	to	94	„

A portion of the pig-iron is used for casting and in the pipe foundry and the rest is sold as pig-iron.

The present daily output of the by-products is :—

Lime acetate	5·5 tons.
Alcohol	600 gallons.
Tar	12 tons.

Kankar from Dronachallam, Kurnool district, was being used primarily for the manufacture of acetate, but now lime-kankar is being obtained from several places in the state.

The output of by-products for the years 1924-1928 has been :—

——	1924	1925	1926	1927	1928
Acetate (in tons) . .	1,286	1,318	1,396	1,579	1,32
Alcohol (in gallons) . .	109,795	106,800	125,426	136,926	145,587
Tar (in tons) . . .	2,501	1 648	2,305	2,480	1,915

The sales of these products have been chiefly outside the state. Labour is imported mostly from the Mysore, Tumkur, Kolar and Chitaldrug districts of the state, but a small percentage is also imported from Malabar and Salem. About 350 coolies are employed in the iron mines; they are provided with suitable huts for living purposes.

Goa and Ratnagiri.

The iron-ore of the Goa and Ratnagiri areas is of Dharwar age and crops out in the midst of laterite. As seen at the outcrop, it is a hard ore composed either of limonite or of hæmatite containing minute crystals of magnetite. At Bicholim, 22 miles from the port of Marmagao in Goa, the principal ore band has been traced for a distance of 7 kilometres and is said to vary in width from 30 to 100 metres. Prospecting work carried out by the 'Compagnie des Mines de Fer de Goa' in the Protuguese territory of Goa, and by Messrs. Jambon and Company in the adjoining British district of Ratnagiri indicated that this hard ore is probably the surface, hydrated form of friable schistose micaceous hæmatite, which is found unaltered at a relatively small distance, approximately 50 feet, below the surface. On account, however, of the extent of the outcrops, the hard superficial ore is probably available in large quantities, and, as analyses indicate it to be of high grade, with a very low percentage of silica, and phosphorus below the Bessemer limit, it seems pro-

bable that Goa possesses valuable iron-ore reserves. Some of the deposits are only 4 miles from navigable water and it is therefore not impossible that iron-ore may be mined at some time for export.

Hyderabad.

Production of iron-ore is reported from the following localities, Asafabad, Khammammett, Karimnagar and Nizamabad.

The native smelting industry.

The indigenous methods of smelting iron in various districts in India have been frequently described, and no new features in the methods have recently been noticed. The industry still persists in a few districts of Bengal and Bihar and Orissa; in the Kumaon hills; in Mysore; in the districts ofMalabar, Salem, and Trichinopoly of Madras; in Hyderabad; and in several states in Central India and Rajputana. The industry shows signs of greater activity in the Central Provinces than elsewhere. In the last quinquennial review returns were only received from the districts of Bilaspur and Drug in the Central Provinces, and during the last year of that period 119 furnaces were at work. Returns are now being made from four other districts and from the table it seems that the indigenous industry is gradually dying out. At one locality, Ghogra, in the Jubbulpore district, manganiferous iron-ore is smelted with the production of a steely iron known as *kheri*[1].

TABLE 44.—*Number of iron-smelting furnaces at work in the Central Provinces during the period 1924-28.*

——	1924	1925	1926	1927	1928
Bilaspur	97	103	102	95	102
Drug	25	..	..	11	16
Jubbulpore	..	1	1	1	1
Mandla	..	35	36	47	54
Raipur	107	68	68	48	20
Saugor	..	4	4	3	3
TOTAL	229	211	211	205	196

[1] *Mem. Geol. Surv. Ind.*, XXXVII, p. 595 (1909).

Iron-ore occurs at numerous places along the outer Himalaya, the rocks being similar lithologically to some of the Dharwars of peninsular India. Owing to the abundance of timber and, until recently, to the absence of railway transport by which cheap foreign iron and steel are distributed, the *lohar*, or *agaria*, as the native smelter is sometimes called, flourished to a later date than in the more accessible parts of the Peninsula, and the industry of iron-smelting still persists in a languishing condition. The necessity of curtailing the indiscriminate cutting of forests, the readiness with which a large variety of foreign implements can be obtained in the bazars, and the higher wages obtainable on account of the general progress of the country have all combined to encourage the *lohar* to leave his ancestral calling for other industries, although a few workers still occupy their leisure during slack seasons in smelting, and the native-made product is preferred to foreign iron when it can be obtained readily.

The native smelting industry in Gharwal.

In the higher parts of the Garhwal district the fuel used is the charcoal of the *buran* (rhododendron) and *ayas* (oak), while the *chir* tree (*Pinus longifolia*) is used in the lower hills. The simple 'bloomeries' used are not unlike those generally used on the plains. The purified wrought iron obtained from about one *maund* (82 lbs.) of ore weighs only about 10 pounds; it is made up into rough implements like hoes, hammers, and crowbars.

The *lohars* of Garhwal are regarded as belonging to an upper section of the low-caste *doms*. They regard as the founder of their caste one Kaliya *lohar*, who is supposed to have supplied the Pandavas with their fighting weapons, and he is now propitiated before each smelting operation with an offer of five pieces of charcoal.

Owing to a world-wide slump in the iron and steel trade, the industry was not prosperous in the early part of the quinquennium and its conditions were investigated by the Indian Tariff Board and a measure of protection introduced for steel in 1924. The Steel Industry (Protection) Act was passed in 1924, and granted, up to the 31st of March, 1927, to companies employing Indians, bounties upon rails and fishplates wholly manufactured in British India from material wholly or mainly produced from Indian iron-ore and complying with specifications approved by the

Protection.

(Act No. XIV of 1924.)

Railway Board, and upon iron or steel railway wagons a substantial portion of the component parts of which had been manufactured in British India. These bounties were increased in 1925, and protective duties were suggested.

This act was repealed by Act No. III of 1927, and consequently the payment of bounties ceased on the 31st of March, 1927, but the industry is protected to a certain extent by varying tariffs on different classes of imported steel. This protection is given for seven years commencing from April 1st, 1927, and the Bill provides for a statutory inquiry in the fiscal year 1933-34, to ascertain what amount of protection may still be necessary.

Imports.

Except for the pig-iron and steel produced at Kulti (Barakar), Jamshedpur and Burnpur, the greater part of the iron and steel used in India is imported. The steel furnaces in the Government ordnance factories consume 300 tons of indigenous pig-iron and 2,700 tons of imported pig-iron annually. To the former figure, however, should be added 3,200 tons of high class scrap supplied by steel makers in India, which is produced entirely from indigenous pig. With the exception of about 50 tons of special pig-iron, all pig-iron used by the East Indian Railway works at Jamalpur during the period under review has been of Indian origin. The iron produced by primitive Indian methods probably amounts to less than 1,000 tons a year. The requirements of the country in iron and steel are indicated by the import returns summarised in Table 45. From this it will be seen that the total value of the unfinished and finished iron and steel products imported into India have remained fairly constant during the quinquennium, but the average value has decreased from 65,14,74,267 rupees in the last quinquennium to 49,35,32,283 rupees in the period under review.

Exports.

In 1924 there was a big increase in the toal production of pig-iron in India—from 599,516 tons in 1923 to 872,547 tons in 1924. A large portion of this was exported and the prices at which it proved possible to land cargoes of Indian pig-iron at United States ports led to complaints from American producers and anti-dumping notices are said to have been issued against certain cargoes of Indian pig[1].

[1] *Iron and Coal Trades Review* 1925, p. 757.

TABLE 45.—*Imports into India of Iron and Steel materials during the years 1924 to 1928.*

—		1924	1925	1926	1927	1928	*Average.*
Cutlery and hardware (*a*) .	Rs.	5,72,36,344	5,57,79,585	5,58,83,246	5,67,52,492	5,85,55,191	*5,68,41,372*
Machinery and millwork (*a*)	,,	15,53,44,993	15,95,48,216	15,13,37,077	16,57,87,417	21,04,39,807	*16,84,91,502*
Railway plant and rolling stock (*a*).	,,	8,39,15,058	7,53,44,065	7,14,94,159	8,44,57,576	2,21,41,648	*6,74,70,501*
Iron bars, pig-iron, etc. .	,,	32,46,182	28,96,335	23,12,530	25,16,634	20,75,394	*26,09,415*
	Tons	18,001	17,775	13,503	19,455	14,657	*16,678*
Iron and steel beams, sheets, pillars, rivetts etc.	Rs.	16,68,06,548	15,47,92,396	16,63,32,509	18,25,16,326	18,81,48,943	*17,17,19,344*
	Tons.	682,369	668,920	738,950	871,813	1,013,458	*795,102*
Steel bars, angles and channels, ingots, blooms, billets, etc.	Rs.	3,55,87,206	1,79,31,685	2,41,14,554	2,76,83,218	2,66,84,083	*2,64,00,149*
	Tons	256,549	147,788	228,455	260,389	242,954	*227,227*
TOTAL value .	Rs.	**50,21,36,331**	**46,62,92,282**	**47,14,74,075**	**51,97,13,663**	**50,80,45,066**	*49,35,32,283*

(*a*) Figures for quantities are not available.

TABLE 46.—*Exports of Pig-iron from India during the years 1924 to 1928.*

-- --	1924	1925	1926	1927	1928	*Average.*
	Tons.	Tons.	Tons.	Tons.	Tons.	*Tons.*
To --						
United Kingdom.	8,828	28,708	15,314	21,140	8,920	*16,582*
Germany .	..	11,595	3,166	9,926	8,542	*6,646*
Japan . .	149,697	158,713	230,913	265,226	321,010	*225,112*
United States of America.	97,771	177,180	49,760	67,685	57,897	*90,058*
Other countries	14,759	25,598	16,009	19,983	32,256	*21,721*
TOTAL .	**271,055**	**401,794**	**315,162**	**383,960**	**428,625**	*360,119*
Total value in Rs.	1,79,78,296	1,98,66,537	1,42,19,549	1,74,28,804	2,01,50,789	*1,79,28,695*
Total value in Sterling.	*£1,293,402* (£1 = Rs. 13·9)	*£1,493,724* (£1 = Rs. 13·3)	*£1,061,160* (£1 = Rs. 13·4)	*£1,300,619* (£1 = Rs. 13·4)	*£1,503,790* (£1 = Rs. 13·4)	*£1,330,539*

Throughout the quinquennium the United States of America and Japan were the principal consumers of Indian pig-iron, although there was a big drop in the American consumption in 1926.

Jadeite.

[J. COGGIN BROWN.]

Jade is a name popularly applied to certain semi-precious stones, usually of a green colour, which belong to at least two distinct mineral species, nephrite and jadeite. On account of their toughness, colour and supposed magical properties they have been treasured by

mankind from the earliest times. Celts and carved ornaments of jade and jadeite have been found in many prehistoric sites both in Europe, Asia and North America. These ancient beliefs have descended through the centuries to the modern Chinese who prize and revere the stone which they believe confers on the wearer immunity from accident and ill fortune and is the symbol of purity in private and official life. At the same time an admiration for the remarkable beauty of Burmese jadeite has gradually grown up in western lands where it is rapidly becoming a favourite article of feminine adornment.

Exports and prices.

The winning of the mineral forms an important industry in the Myitkyina district of Upper Burma. A certain quantity of the stone passes by the overland route to Têng-yüeh in Yunnan, where it is marketed, cut, polished and distributed to the western provinces of China, but most of it finds its way down to Rangoon, through Mogaung and Mandalay, whence it is exported to the Straits Settlements and various Chinese destinations.

The official returns of jadeite production are anomalous and little reliance can be placed upon them. The export figures which have been used as a fairly reliable indication of the state of the industry in the past are now vitiated as the trans-frontier trade returns are no longer collected. Such figures as exist, however, are given below:—

TABLE 47.—*Production of Jadeite during the years 1924 to 1928.*

YEAR.	Quantity.	*Value.*	Value per cwt.
	Cwts.	*Rs.*	Rs.
1924	2,630·4	*8,60,493*	327·1
1925	1,696·5	*2,67,148*	157·5
1926	1,203·9	*2,34,456*	194·7
1927	2,227·0	*2,39,064*	107·3
1928	2,845·0	*2,85,984*	100·5
Average	*2,120·6*	*3,77,429*	*177·4*

TABLE 48.—*Exports of Jadestone from Burma during the years 1924-25 to 1928-29.*

YEAR.	Quantity.	*Value.*	Value per cwt.
	Cwts.	*Rs.*	Rs.
1924-25	2,766	*7,06,800*	255·5
1925-26 *	972	*1,62,751*	167·4
1926-27 *	2,139	*4,70,225*	219·8
1927-28 *	1,961	*3,02,440*	154·2
1928-29 *	2,698	*5,82,471*	215·8
Average .	*2,107*	*4,44,937*	*211·2*

* No transfrontier returns available.

As they stand the production and export returns practically balance but the amounts crossing the land frontiers into China are not shown for four of the years in question, so that in reality the export figures would be considerably higher than those of actual production. It is also certain that the quantities of the stone used in the manufacture of jewellery in the cutting centres of Mandalay and Mogaung, and either absorbed in Burma or exported without appearing in the returns, would go to swell the figures. Another important factor with the same effect is the amount of mineral lost in cutting the stone before export.

There has unquestionably been a marked decline in exports and the average figure of 2,107 cwts. compares very unfavourably with 4,628 cwts., the average not only for the previous quinquennium but approximately that of the three similar earlier periods. In the trade the decline is said to be due to troubled political conditions in China. The average value of the exported stone has also declined remarkably by about 34 per cent. from Rs. 318·8 to Rs. 211·2 per cwt. though it is doubtful whether these figures possess any real significance.

Value of jade.

To the Chinese the different varieties of both nephrite and jadeite and possibly other minerals of similar appearance are known as *Yu* or *Yu-chi*. They are emblems of virtue and stand high in the ranks of their precious

stones. Bowenite, a jade-like variety of serpentine passes on the north-west frontier under the name of *sang-i-yeshm* and is frequently met with in eastern bazaars carved into drinking cups, trinkets and beads. Chinese dealers in Burma classify jadeite into many different kinds the values of which fluctuate within very wide limits. This is not surprising in a mineral which may possess any colour from pure white, through all the shades of green to amethystine, mauve, violet and light blue, yellow and orange, to various tints of brown, red and black. One broad distinction is made between *aye* and *athakyauk* (*kyauk* is Burmese for stone) and to the former belong all the beautiful green varieties of varying degrees of colour, translucency and texture. The mineral has no fixed market value and the prices which it brings depend on the taste of the buyer and the state of his pocket. The most precious of all the classes in the *ayekyauk* section is known as *myaye*; it is a uniform translucent green which is best compared with the emerald or, in Chinese phraseology, with the green in a peacock's tail. It is worth anything from Rs. 500 to Rs. 10,000 per *viss* (1 *viss*=3·6 lbs.). *Shweluye* has a lighter tint of green with brighter spots and streaks. It is said to be worth from Rs. 100 to Rs. 5,000 per *viss* and like the former is used in the manufacture of expensive jewellery. Other varieties of the same section include *peye*, a pea green stone of much the same value as *shweluye*, and *latye*, a translucent sage green variety valued at Rs. 500 to Rs. 1,000 per *viss*. For fancy cut pieces of perfect specimens of some of these varieties values are officially stated to range between Rs. 20 and Rs. 1,500 per *tola*, (1 *tola*=180 grains).

Turning now to the other section, or *athakyauk* *atha* in Burmese means flesh, but it here includes all the brilliant white varieties of the mineral of all degrees of translucency and limpidity. The ordinary cheaper varieties include *athayo*, *hnawswe* and *athapukyi*, which vary in value from a few annas to as many rupees per *viss*. They are used in the manufacture of cheap jewellery, pipe stems, plates, cups and saucers, etc. *Pantha*, which possesses a certain amount of opacity is used for decorative inlaid work.

It is unnecessary to burden this list any further with vernacular terms and it only remains to state that of the unusual colours the shades of mauve, violet, blue and amethystine are the more valuable ranging from a few rupees up to Rs. 500 per *viss*, orange and brick red tints attain a maximum of Rs. 300 per *viss*, yellow comes next

at Rs. 200 followed by rust red which like the others starts at about Rs. 20 for the poorer kinds but only reaches Rs. 100 per *viss*, while black jadeite can be purchased for Rs. 10 to Rs. 80 per *viss*. In the compilation of this section the writer has derived much assistance from lists courteously furnished by Mr. C. W. Chater, the well-known authority on jade, and by the Deputy Commissioner of Myitkyina.

The figures quoted certainly prove that the values of the mineral given per cwt., in the export returns, are fallacious.

Composition.

Two distinct minerals are included in the term *jadestone* or *jade*, the true jade or nephrite, which is a variety of tremolite or actinolite, a silicate of calcium and magnesium, $CaO \cdot 3MgO \cdot 4SiO_2$, and a member of the amphibole group; and jadeite, a compact alkali pyroxene, $Na_2O \cdot Al_2O_3 \cdot 4SiO_2$, a silicate of sodium and aluminium. The white and greenish varieties of the stones are often confused and they are both equally valued by the Chinese. Though tough and splintery like jade, jadeite is slightly harder, considerably heavier and more easily fusible than the other.

No jade (nephrite) of the kind that would be regarded as a marketable stone is known in India; but a mineral, having the essential composition and approaching coarse jade in physical characters, is known in South Mirzapur[1]. True jade, however, has been worked in the Karakash valley in South Turkestan for many centuries[2].

Mode of occurrence.

The only jadestone of commercial importance within the Indian Empire is the jadeite that occurs in the valley of the Uru river, a tributary of the Chindwin, in the Mogaung sub-division of the Myitkyina district, Upper Burma. The most interesting of a number of occurrences in this region is at Tawmaw (25° 41′ 13″ ; 96° 15′ 28″) where alluvial jadeite has probably been known to occur for a very long time but where the mineral was first discovered *in situ* about 50 years ago. Accounts of the occurrences have been published by Dr. F. Noetling[3] in 1893, and by Dr. A. W. G. Bleeck in 1908[4]. A systematic geological survey of the region has lately been undertaken by Dr. H. L. Chhibber of the Geological Survey of India

[1] F. R. Mallet; *Rec. Geol. Surv. Ind.*, V, p. 22 (1872).
[2] *Cf.* papers quoted by Mallet in Manual, Geology of India, Part IV, p. 85 (1887).
[3] *Rec. Geol. Surv. Ind.*, XXVI, pp. 26-31 (1893).
[4] *Ibid*, XXXVI, pp. 254-295 (1908).

and the short summary given below is based on the results of his work.

The Tawmaw dyke, which is under active exploitation, and the three others of Meinmaw, Pangmaw and Namshamaw, all of which bear deserted outcrop workings, consist of albite-jadeite rock intruded into the northern end of a great elongated mass of partially serpentinised peridotites which has already been traced for a distance of over twenty miles in an approximately N.E.- S.W. direction. Its southerly limits are still unknown.

The ultrabasic rocks are themselves intrusive into a series of crystalline schists which appear to encircle them. They consist of graphite, glaucophane, vesuvianite, hornblende, chlorite, kyanite and quartz- schists together with igneous rocks ranging from diorites and gabbros to pyroxenites and perknites; epidiorite derived from gabbro is the commonest type. The more important varieties of the ultrabasic intrusives are altered dunites, mica, hornblende- and diallage- peridotites, pyroxenites and amphibolites. Brecciation and serpentinisation is wide-spread and various varieties of serpentine such as antigorite, marmolite and the massive dark green mineral occur.

On the Tawmaw dyke are situated the two mines of Dwingyi and Kadondwin which really consist of a series of shafts from which a number of drives have been made along the dyke itself. As exposed in the Kadondwin at the present time, the jadeite occurs in the form of large lenses from 5 to 7 feet thick in the albite of the footwall side. A thin layer of amphibolite often separates the two minerals while the enclosing rocks consist of chloritic schist and brecciated serpentine. The existing working face is about 21 feet across and on the hanging wall side is filled in with a breccia composed of amphibolite, albite and jadeite in a calcareous matrix.

Dr. Bleeck believed that the jadeite was formed as a result of the metamorphism of an albite-nepheline rock but according to Dr. Chhibber the mineral is an original magmatic segregation product.

The mines are only worked for three months during the year and are flooded every rainy season; methods are crude in the extreme, though the use of compressed air drills and steam driven hoists has been introduced lately.

In addition to these underground workings large quantities of jadeite are won in the form of alluvial boulders from certain Tertiary

deposits and from the Uru boulder conglomerate, both of which fringe the great serpentine mass, with its jadeite albite dykes, on the east. The Tertiary rocks consist of sandstones, shales and conglomerates and in the latter, boulders of serpentine and jadeite are of frequent occurrences. Most of the workings, tunnels, quarries and pits are grouped around Kansi (25° 47′ 1″; 96° 22′ 48″), Lonkin (25° 39′ ; 96° 22′) and Hwehka (25° 28′ 32″; 96° 16′ 43″).

The Uru boulder conglomerate, which is often hundreds of feet thick and is believed to be of sub-Recent Age, contains water-worn boulders of most of the metamorphic and igneous rocks of the district, together with serpentine and jadeite. Active workings in it are mostly clustered around Hpakan (25° 36′ 38″; 96° 18′ 40″) and Mamon (25° 35′ 10″ ; 96° 15′ 57″). Jadeite boulders are also obtained by diving into the pools of the Uru river which they have reached by the ordinary processes of recent denudation.

History of the jadeite trade.

The following notes on the history of the jadeite industry are taken from the Myitkyina District Gazetteer where the interested reader will find a full account of the complicated administrative systems which have grown up around the industry as a heritage from the past. In the following paragraphs the term *jade* is used in its generic sense, referring in the case of Burma to jadeite.

According to Mr. Marry of the Chinese Consular Service, the discovery that green jade (jadeite) of fine quality occurs in Northern Burma was made accidentally by a small Yunnanese trader in the thirteenth century, who, to balance the load on his mule, picked up a piece of stone, which was later found to be jade of great value. For some centuries small pieces of stone found their way across the frontier, but it was not until 1784, after protracted hostilities between Burma and China, that a regular trade was opened between the two countries and then the Chinese soon discovered the position of the jade producing district. At the beginning of the nineteenth century the Burmese kings seem to have become aware of the importance of the jade trade and the revenue it might yield, and in 1806, a Burmese collectorate was established at the site of what is now the town of Mogaung, which became the head-quarters of the jade trade in Burma. The Kachins, in whose country the jade

deposits are situated, and who were regarded as the absolute owners of all the jade produced, brought the mineral to Mogaung, where it was sold to the Chinese. When it was ready to leave Mogaung an *ad valorem* duty of $33\frac{1}{3}$ per cent. was levied and a permit issued. Payments were made in bar silver—at first fairly pure, but later on debased with lead (rupees did not come into general use until 1874).

The period of greatest prosperity of the jade trade was between 1831-40, during which time at least 800 Chinese and 600 Shans were annually engaged in business and labour at the mines. All the stone went by one of the several routes to Yunnan Fu, then the great emporium of the jade trade, where Cantonese merchants bought the rough stone and carried it to Canton to be cut and polished. In 1841, war broke out between Great Britain and China and the hostilities at Canton soon affected the jade trade, so that the Cantonese merchants ceased to go to Yunnan Fu to buy stone. Stocks accumulated and Yunnanese traders ceased visiting the mines. The trade passed through various vicissitudes, but it was not until 1861 that it really improved again. From that date, when the first Cantonese merchant arrived in Mandalay and made a fortune by buying up all the old stocks of jade, till now, the bulk of the stone has been carried by sea to Canton. During the ensuing years, the jade dues were sometimes collected in the orthodox way—by the Collector at Mogaung—whilst in other years the tax was farmed out; but the King of Burma dissatisfied with the revenue thus obtained from jade, tried in some years to purchase all the material himself direct from the Kachins at the mines. In such years the Kachins, preferring the former revenue methods, curtailed the output and produced pieces of inferior quality only. The revenue accruing to the King from the jade dues varied from Rs. 10,000 per annum to Rs. 50,000, being least when the King tried to purchase the jade himself. With the British occupation of Upper Burma the tax was farmed out to Leenpin, who made himself so unpopular by his methods of collecting the tax that he was murdered at Mogaung. The first British visit to the mines was made in 1888, by Major Adamson with a column of British troops. The tax of $33\frac{1}{3}$ per cent. on output is still farmed out by Government.

Before the mineral leaves the mines certain payments have to be made to the local Kachin chiefs (the Kansi or Hwehkha *duwas*),

which are stated to be a ten per cent. *ad valorem* tax known as *manhumanta* and a toll of Rs. 2-8 on every mule load, or Re. 1 on every coolie load of jadeite removed. The stone is then taken to Mogaung where the *ad valorem* royalty of $33\frac{1}{3}$ per cent. is assessed by a valuation committee of merchants, and has to be paid before the stone is permitted any farther afield. The right to collect this royalty and another one of 5 per cent. on the amber from the Hukong valley is still farmed out by Government. During the period under review the amount realised on this account was Rs. 95,600 per annum, Rs. 34,400 per annum less than in the previous period. This system is particularly pernicious and is one which readily lends itself to abuses, it being to the interest of the lessee of the royalty as well as to that of the producer to keep the returns of production as low as possible, and it is probable that much material is smuggled away, thus escaping the payment of royalty.

Jadeite has been found in the Mawlu township of the Katha district, Upper Burma, and is also reported from Tibet. Jade is stated to occur in the corundum quarries of Pipra, Rewah State.

Lead.

[G. VERNON HOBSON.]

The history of the lead industry in India continues to be, for all practical purposes, the record of the exploitation of the great ore deposit at Bawdwin in the Northern Shan States of Burma and the development of the metallurgical and milling processes there. The current records of this enterprise open during the quinquennial period 1909-13 with the production of 46,000 tons of lead; during the next period, 1914-18, in spite of the difficulties caused by the war, 73,817 tons of lead were extracted; in the next period, 1919-23, the production had increased to 161,902 tons. During the period under review the amount of lead extracted has again increased to 297,715 tons (includes 5,101 tons of antimonial lead) valued at Rs. 11,24,41,670. It is satisfactory to record that with the exception of 1925, when there was a small drop due to mine fires, there has been a steady increase in production (see Table 49). The revenue derived from the sale of lead has not shown an increase corresponding to the growth of output owing to a falling price for the metal.

TABLE 49.—*Production of Lead from Bawdwin during 1924-28.*

	Total ore mined.	Lead extracted.	*Value in Rupees.*	*Value in Sterling.*
	Tons.	Tons.	*Rs.*	£
Average 1919-23	*151,988*	*32,380*	*1,18,34,837*	*866,380*
1924	287,777	50,559 (*a*) 1,200	*2,32,00,868* *3,06,172*	*1,691,154**
1925	321,389	46,175 (*a*) 1,100	*2,18,23,219* *2,83,909*	*1,662,190†*
1926	362,505	53,273 (*a*) 1,057	*2,22,74,134* *3,20,500*	*1,686,167‡*
1927	449,817	65,464 (*a*) 503	*2,18,94,677* *1,33,065*	*1,643,861‡*
1928	442,503	77,143 (*a*) 1,241	*2,18,88,115* *3,17,011*	*1,657,099‡*
TOTAL	**1,863,991**	**292,614** **(*a*) 5,101**	*11,10,81,013* *13,60,657*	*8,340,471*
Average 1924-28	*372,798*	*58,523* (*a*) *1,020*	*2,22,16,203* *2,72,131*	*1,668,094*

(*a*) Antimonial lead. * (£1=Rs. 13·9). † (£1=Rs. 13·3). ‡ (£1=Rs. 13·4).

In the neighbourhood of Bawdwin an ancient series of rhyolitic tuffs, flows, and breccias, with coarse felspathic grits has been intensely crushed and dislocated by overthrust faulting. The main ore channel is in this zone, and ascending ore-bearing solutions have metasomatically replaced the congenial materials in the tuffs, giving rise to sulphides along what is known as the Bawdwin fault. This fault has been traced for a length of approximately 7,000 feet although development and exploration work has so far covered only a distance of 2,600 feet along it. The work has disclosed the presence of two main ore bodies named respectively the Chinaman and the Shan lodes. The Shan lode appears to be a northward extension of the Chinaman lode offset to the east by the Yunnan fault. Recent development work tends to confirm the idea pre-

viously held that there is a northward pitch to the ore body with the result that the major part of the Shan lode will occur at depth. It is therefore confidently expected that the tonnage of ore developed in this lode per foot of depth will be greater than in the past and also that the limits of payable ore will extend in depth as far north as the Goldhole fault, at which point the ore channel is cut off. The ore bodies are confined to the rhyolite tuffs, locally designated the Bawdwin tuffs. Underlying these tuffs there is a sedimentary bed, locally called the Yunnan bed, having an approximate thickness of 150 feet and unfavourable for mineral deposition. The lower levels in the Chinaman lode are now encountering this bed with the result that there is a lower yield of ore developed per foot of depth. Again underlying the Yunnan bed there are further rhyolite rocks of which the composition is reported to be favourable for mineral deposition. In the event of the underlying rhyolites being mineralised, as appears probable, then the development of ore per foot of depth in the Chinaman section may again rise when the Yunnan horizon has been passed.

The Chinaman ore-body has been developed for considerably more than 1,000 feet and varies in width from a few feet to over 100 feet, maintaining on some levels an average width of 50 feet of solid sulphides over a distance of 1,000 feet. 'It is primarily a zinc-lead-silver ore-body with small amounts of copper along the edges' writes M. H. Loveman.[1] A. B. Calhoun[2] writes 'The ore is an intimate mixture of galena and sphalerite and in many places also of chalcopyrite, although the latter is often found in parallel bands alongside the former as pure unmixed chalcopyrite. The mixture of galena and sphalerite contains approximately 1 oz. of silver for every per cent. of lead.' To quote Mr. Loveman again, 'A cross-section through the Chinaman lode shows a central core of solid zinc-lead ore, with the zinc generally, but not invariably, in excess of the lead. On both sides of this central core are alternating bands of solid ore and mineralised tuff. These bands parallel the main body in strike and dip, but are not persistent themselves, coalescing and pinching out and in reality forming a sort of stockwork. These bands are generally high in lead and comparatively low in zinc. A slight percentage of copper is generally

[1] *Rec. Geol. Surv. Ind.*, Vol. XLVIII, pp. 121-78 (1917); and *Trans. Amer. Inst. Min. Eng.*, Vol. LVI, p. 181 (1917).
[2] *Ibid*, Vol. LXIX, p. 211 (1923).

found on their edges. From both sides of these bands the mineralisation extends far out into the tuff, gradually merging into barren rock. Occasional seams and patches of ore are found at considerable distances. There is no sharp boundary between mineralised and unmineralised country rock as a general thing, although this condition is approximated in a few places by fault planes. The extreme richness in metal content of the ore-body is best shown by the fact that a block roughly 800 feet long by 600 feet deep by 30 feet wide contains about 1,750,000 long tons with an average value of approximately Ag. 30 oz., Pb. 31 per cent., and Zn. 29 per cent. A theoretical block of the same size of solid galena and sphalerite with equal amounts of Pb. and Zn., would contain approximately 2,300,000 long tons. Thus the block in the mine is over 75 per cent. solid lead and zinc sulphides......A gradual thinning of the ore-body takes place on approaching the underlying sediments.'

Mr. Calhoun[1] sums up his years of experience of the Chinaman ore-body as follows :—'Taken as a whole, the southern end predominates in zinc-lead ore; the middle in more equal quantities of both; and in the northern end the zinc is partly replaced by copper. In practically all sections the ore along the hanging wall is the highest grade, with the lead predominating over the zinc, but towards the centre or the foot-wall the zinc contents increase until, in many sections, the zinc predominates.

'Still further toward the foot-wall the ore becomes lower grade and below what is classed as ore until it is only mineralised; the lead however predominates and is often found as pure crystals of galena. There is no definite stoping limit towards the foot-wall side, except what is arbitrarily fixed as the limit of commercial ore (20 per cent. combined lead-zinc with whatever silver it contains). Later, this arbitrary value may be lowered and another 2,000,000 tons of low grade ore added to the reserves.' The arbitrary limit is still maintained but at the last general meeting of the Corporation the working of some of the lower grade material was foreshadowed.

The development of the Shan lode early brought to light the occurrence of high-grade copper ore with some silver values. As a consequence, during the period under review, the production of 40 to 41 per cent. copper matte became a steady factor at Namtu. (*See* Copper).

[1] *Trans. Amer. Inst. Min. Eng.*, Vol. LVI, p. 183 (1917).

The mine was originally worked by the Yunnanese Chinese probably for hundreds of years and abandoned by them in the sixties of last century, when their galleries reached permanent underground water-level and the Mahomedan revolt in Yunnan rendered their tenure amongst the Kachin tribes insecure. Modern development commenced in 1902, after the attention of Europeans had been drawn to the vast heaps of lead slags left by the Chinese from their silver-smelting operations. In 1909, the first production of lead and silver from the old slags was made. Early mining exploitation was not encouraging but after the discovery of the remains of a large ore-body in the 'Dead Chinaman' tunnel in 1912, development has been active and successful and the many thousands of feet of driving, cross-cutting, and rising have now proved the Chinaman lode to be one of the largest and richest silver-lead-zinc ore-bodies in the world.

The ore-body was originally attacked by sinking the vertical shaft in the Bawdwin valley, but once the potential riches of the deposit were realized, a commencement was made in opening up at deeper levels, by driving Tiger Tunnel from a point nearly two miles away. This is 653 feet below the zero-level at Bawdwin, is double tracked from the portal to the Marmion shaft and is 9 feet by 8 feet inside measurement. It corresponds to the Number 6 level of the mine and is the main haulage and drainage level. All the ore, as it is mined, is raised or lowered to this level and hauled out by electric locomotives to the tipple plant and storage bins at Tiger camp. As originally driven the Tiger tunnel was within the Chinaman ore-body at the mine end and was therefore liable to damage resulting from mining operations in the lode itself. A diversion tunnel lined with masonry was accordingly driven in the country rock on the east side of the Chinaman ore-body and connected up to cross-cuts in the lode so that any chance of transport being interrupted through movements in the ore-body in the future has now been removed. The above work was completed early in the period under review. The replacement, in Tiger tunnel, of timber by masonry has also been carried out and a total distance of 5,194½ feet has been secured in this way.

Another most important piece of work has been the sinking of a large, vertical, circular shaft in the country rock on the west side of the Shan lode. This shaft has now been named the Marmion shaft. The shaft is lined with masonry and equipped with steel-

work for guiding cages, carrying cables and pipe lines, etc. The steel head-frame was erected, and a temporary winder placed in position in 1924. In 1925, the shaft had been completed to No. 6 level (Tiger tunnel level) and equipped with temporary cages. On the outbreak of fire that year the two internal shafts had to be sealed off in the fire area and the circular shaft remained the only means of transportation for timber and stores, and as a travelling way between the various levels, Tiger tunnel, and the surface. On the recovery of the two internal shafts from the sealed area the sinking of the circular shaft was continued. In 1926, two electric winders were erected in a new steel winder-house and a large cage with balance weight capable of accommodating 32 men per trip, or one of the large mine cars in use, was built for No. 2 winder. No. 1 winder operates two small balanced cages. By the end of June, 1928, the shaft had been completed with masonry and steelwork to a total depth of 1,070 feet. Both winders were operating cages to No. 9 level. Further sinking was in progress, without interruption to the normal working of the shaft.

In view of the increasing tonnage of ore that will have to be raised through this shaft as time goes on, skips are to be installed to operate below the two small balanced cages. A self-dumping device for the skips is placed at the level of Tiger tunnel so that the ore can be discharged into hoppers from which the cars on the main haulage will be loaded. The self-dumping device can be put out of action during the hoisting and lowering of men and materials to and from the surface. The additional bracing and larger pulley-shafts and plummer blocks needed for skip-haulage have been installed in the head-frame. The skips have been built and only await the completion of the under-ground work before being installed. Arguments for and against different types of shafts and winding devices have recently been discussed by Mr. Calhoun[1] in a paper on fundamental hoisting problems. The two internal shafts, which are in the Chinaman ore-body, are used for hoisting and lowering men and supplies.

The ore at Bawdwin is so heavy and friable that it must be closely timbered to support any opening and the ore-body is so wide that it requires mining in sections. A combination square-set rill system of stoping has been evolved to meet the conditions, and the

[1] *Eng. Min. Journ.*, Vol. 122.

method of timbering has been described in a recent paper by R. S. H. Richards[1]. Waste material for filling is obtained from the surface and passed into the stopes through special rises.

In 1919, the Burma Mines, Limited, which up to that time had been a London concern, was reorganized with its headquarters in Rangoon as the Burma Corporation, Limited. This corporation now possesses a total authorized capital of 20,000,000 shares of Rs. 10 each of which 13,541,689 shares have been issued. A first mortgage 8 per cent. convertible debenture issue of £1,000,000 has been redeemed during the period under review. The magnitude of the finances involved and a study of the ore reserves given below will convey some impression of the size of this industry that has been developed in the heart of the Shan jungles, 600 miles inland from Rangoon and only 40 miles from the Chinese frontier.

TABLE 50.—*Ore reserves as on July 1st, 1928.*

	Tons.	AVERAGE ASSAY VALUE.			
		Ag. Ozs.	Pb. per cent.	Zn. per cent.	Cu. per cent.
Total Chinaman ore-body (proved and probable).	5,470,066	23·5	27·3	17·4	0·49
Total Shan lode	1,260,236	17·8	19·7	10·3	3·60
Total Palaung lode . . .	14,910	26·6	11·7	11·0	8·80
Total (proved and probable) .	6,745,212	22·4	25·8	16·0	1·10
Extracted	2,652,461	23·8	25·7	16 0	1·01
Reserve in mine	4,092,751	21·5	25·9	16·0	1·15
Ore stocks	6,933	20·5	15·0	7·8	5·60
Total ore-reserves	4,099,684	21·5	25·9	16·0	1·16

[1] *Bull. Inst. Min. Met.*, No. 281, Feb. 1928, Lond. and *Trans. Inst. Min. Met.*, Vol. XXXVII, pp. 324-64.

Included in these ore reserves are approximately 350,000 tons of copper ore averaging about 13 per cent. Pb. ; 8 per cent. Zn. ; 7 per cent. Cu. ; and 18 ounces of silver to the ton.

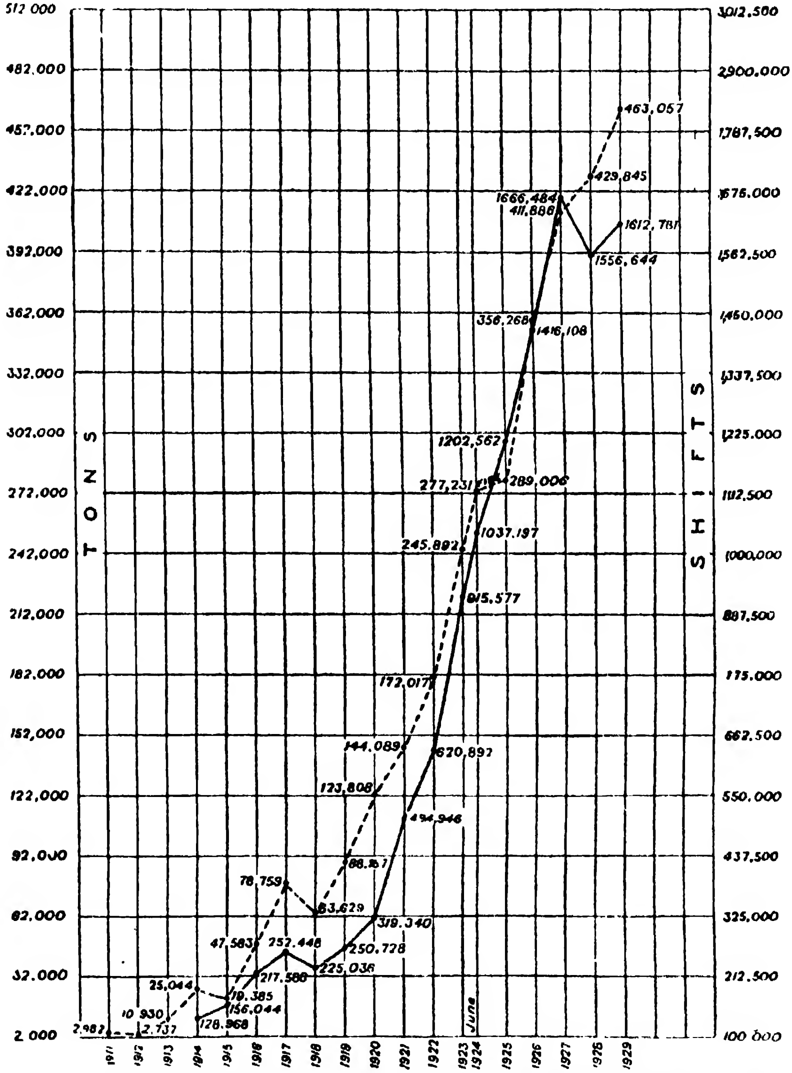

FIG. 11.—*Production of lead-ore and number of shifts worked in the Bawdwin mine since 1911.*

We are indebted to the Corporation for the following note on the present state of the property and the progress made during 1924-28.

Extensive development has been done on both the Chinaman and Shan lodes with satisfactory results, inasmuch as the tonnage of ore reserves at the 31st of December, 1928, was about 4,000,000 with only a slight decrease in grade arising from the completed development of No. 7 level and the considerable development of Nos. 8 and 9 levels.

This work was accomplished and progressively increasing tonnages of ore mined despite the incidence of fires in the mine, the first of which occurred on the 16th of December, 1924, at the bottom of Rise 1604 South, No. 4 level. The area affected was sealed off and the gases allowed to accumulate and smother the fire. The barricades were opened on the 28th of December, and the fire was found to be out. Considerable damage, however, resulted from the collapse of stopes and drives as a consequence of the burning of timber supports and the flooding of the area with water.

On the 1st of February, 1925, a second and much more disastrous fire occurred in the Rise 1180 South, between Nos. 3 and 4 levels. The fire developed rapidly and it was decided to erect barricades on all levels at about co-ordinate 1135 South to seal off the whole area affected, which extended to the southern limits of the Chinaman ore-body. The fire was under control by the end of February and, thereafter, the extraction of ore from the unaffected areas was done in the best manner possible.

Gradually, the affected areas have been reclaimed until, at the end of 1928, the whole of the stopes on Nos. 3, 4, 5 and 6 levels have been recovered, the only sealed area being that on No. 2 level between co-ordinates 1242 S. and 1500 S.

The grade of the ore mined was detrimentally affected for many months but, gradually, that deficiency was overtaken, until, for some time past, increased tonnages of ore of an improved grade have been mined, enabling the average monthly production for the past twelve months of 6,428 tons lead and 617,060 ozs. silver to be obtained. During the months immediately following the second fire the tonnage of copper ore mined and treated was increased considerably, resulting in the production of more high-grade copper matte, which served as a partial set-off against the reduced lead and silver production.

Our mining policy upto date has been chiefly confined to the development and extraction of the high-grade ores in the Chinaman and Shan ore-bodies, which occur in a well-defined ore channel along what is known as the Bawdwin fault, which latter can be traced for a length of approximately 7,000 feet.

Development and exploration work have, so far, covered only a longitudinal distance of about 2,600 feet along this fault and, whilst we have no knowledge of the existence of other payable deposits in the ore channel, we have recently instituted and are now vigorously prosecuting an exploration policy which we hope will prove that payable ore is not entirely confined to the areas in which we have worked hitherto.

During 1928, a geological examination of the mine was made by Dr. Malcolm Maclaren. His visit enabled him to confirm his previous views that the rhyolite tuffs, locally designated Bawdwin tuffs, are more favourable for mineral deposition than the underlying bed of sedimentary rock on which they rest and that the chemical composition of the rhyolite rock again underlying the sedimentary bed is wholly favourable to ore deposition.

So far, therefore, as established geological conditions are concerned, Dr. Maclaren's opinion is that development in the southern, or Chinaman, section of the mine has reached the horizon at which the Yunnan bed of sediments has been encountered, and that the tonnage of ore that will be exposed per foot of depth in it is likely to be much less than in the overlying Bawdwin tuffs, in which development in this section has hitherto been carried on.

In the northern, or Shan, section of the mine his opinion, again as regards established geological conditions, is that the Bawdwin tuffs will persist to a greater depth because of their northerly pitch, and that future development in them will yield a larger tonnage of ore per foot of depth than in the past, and that the limits of payable ore will gradually extend in depth as far north as the Goldhole fault, *i.e.*, to about 1,200 feet north of the Marmion shaft which is 500 feet beyond the most northerly point at which ore in payable quantities has been exposed in the levels so far developed in this section. For these reasons he considers that the Shan section will yield the greater tonnage of ore in the future as the Chinaman has in the past.

The result of development carried out during the year 1928 would appear to lend support to this view for a considerably larger

tonnage was developed from exploratory work in the Shan than in the Chinaman section.

Marmion shaft—the circular main shaft—has been sunk to a depth of 1,107 feet and masonry-lined to within 7 feet of the bottom, or 48 feet below No. 9 level. The capacity of the air-compressing plant is now 9,000 cubic feet of free air at 90 lbs. pressure. The capacity of the concentrating mill has been increased to 1,000 tons per day including the provision of a flotation plant, wherein the average monthly production for 1928 was :—

	Tons.
Coarse lead concentrates	6,791
Float lead concentrates	3,573
Zinc concentrates	5,078

all of an improved grade as the result of the erection of more efficient metallurgical machinery. Improvements and addition made at the smelter and refinery have brought the production capacity up to 7,000 tons of refined lead and 650,000 ozs. of silver per month. The marketable products have been increased by the addition of copper nickel speiss, from which revenue was obtained during 1928, for the first time. During the year 1928, the Corporation produced 77,143 tons of refined lead and 7,404,728 ozs. of silver, an increase of 73·1 per cent. for lead and 52·8 per cent. for silver, compared with the respective outputs for the year 1923.

Southern Shan States.

Small quantities of lead-ore continue to be raised in the Southern Shan States. In the vicinity of Mawson, a village lying 18 miles north of Heho, the terminus of the Southern Shan States branch of the Burma railways, there occur nodules of galena in yellow clay filling clefts and fissures in limestone. At the Bawzaing mine in this area lead concentrates are produced. Over the Mawson area prospecting has continued coupled with the shipment of old Chinese slags, which occur in some quantity over this area. A typical analysis of this slag is quoted by Rundall[1] in a recent paper on the Mawson ores.

Yamethin.

A small output of lead-ore was reported from the Yamethin district in 1925 and 1926. An occurrence of galena in limestone was opened up in 1908-09 by the Mt. Pima Mining Company in the Yamethin district, but without success. The production above-mentioned is probably from prospecting work in the same area.

[1] *Trans. Inst. Min. Met.*, Vol. XXXVII, pp. 27-49.

TABLE 51.—*Production of Lead-ore during 1924-28.*

	Average 1919-23.			1924.		
	Quantity.	Value.		Quantity.	Value.	
	Tons.	Rs.	£	Tons.	Rs.	£
Burma—						
Northern Shan States	151·988	(a) 1,18,34,837	898,574	287,777	(a) 2,35,07,040	1,691,154*
Southern Shan States	87	7,722	562	22,509	49,000	3,525*
Yamethin	..	..	..	..	..	..
Rajputana—						
Jaipur State	..	..	..	..	..	..
TOTAL	(b) 152,076	(b) 1,18,42,728	(b) 899,153	310,286	2,35,56,040	1,694,679

	1925.			1926.		
	Quantity.	Value.		Quantity.	Value.	
	Tons.	Rs.	£	Tons.	Rs.	£
Burma—						
Northern Shan States	321,389	(a) 2,21,07,128	1,662,190†	362,505	(a) 2,25,94,634	1,686,167‡
Southern Shan States	445	59,525	4,476†	375	55,995	4,179‡
Yamethin	20	800	60†	24	960	72‡
Rajputana—						
Jaipur State	7	1,300	98†	6·6	1,170	87‡
TOTAL	321,861	2,21,68,753	1,666,824	362,910·6	2,26,52,759	1,690,505

	1927.			1928.			Average 1924-28.		
	Quantity.	Value.		Quantity.	Value.		Quantity.	Value.	
	Tons.	Rs.	£	Tons.	Rs.	£	Tons.	Rs.	£
Burma—									
Northern Shan States	449,817	(a)2,20,27,742	1,643,861‡	442,503	(a)2,22,05,126	1,657,099‡	372,798	(a)2,24,88,334	1,668,094
Southern Shan States	960	96,000	7,164‡	1,151	1,15,170	8,595‡	5,088	75,138	5,588
Yamethin	..	..	..	..		..	9	152	26
Rajputana—									
Jaipur State	..	..	..	..	..	..	1	494	317
TOTAL	450,777	2,21,23,742	1,651,025	443.654	2,23,20,296	1,665,694	377,896	2,25,64,118	1,673,745

(a) Value of lead extracted, see Table 49. * (£1 = Rs. 13·9). † (£1 = Rs. 13·3). ‡ (£1 = Rs. 13·4). (b) Including a small production from Drug, C. P.

Indian localities.

The only production of lead-ore reported from India proper during the period under review has been from Panjori in Sewai Madhopur, Jaipur State.

As a matter of academic interest it may be mentioned that two specimens sent in for identification to the laboratories of the Geological Survey proved to be pyromorphite. This mineral had not previously been recorded from India and only doubtfully from Burma. One of the specimens was reported to have come from one of the feudatory states of the Central Provinces, and the other from Chandun in the Bhagalpur district of Bihar in which district lead-ores have long been known to exist.

Galena was reported during the period under review from two localities in Chitral. In one case the mineral was said to occur at Gazan high up on the left bank of the stream draining from the Tui pass and in the other with azurite (derived from copper pyrite) at Chapari.

Table 51 shows the tonnage and value of lead-ore produced during the quinquennial period.

Magnesite.

[E. H. [PASCOE.]

Salem district.

The Chalk hills lying between the town of Salem and the Shevaroy hills in Southern India derive their name from the general effect of the network of white magnesite veins, which are prominent over an area of about 4½ square miles. The occurrence was well known early in the last century, when Mr. J. M. Heath, then 'Commercial Resident' (Collector) at Salem on behalf of the East India Company, was an energetic prospector. The area was described by W. King and R. Bruce Foote in 1864[1] and the origin of the magnesite by alteration of dunite (olivine rock), was first noticed in 1892.[2] A more complete account of the area with map and photographs was published in 1896 by C. S. Middlemiss,[3] who drew special attention to the large quantities of mineral easily available. The network of magnesite veins is seen piercing two great intrusive masses of serpentinised

[1] *Mem. Geol. Surv. Ind.*, IV, pp. 312-17.
[2] T. H. Holland; *Rec. Geol. Surv. Ind.*, XXV, p. 144, footnote.
[3] *Ibid*, XXIX, p. 31 (1896).

ultra-basic rocks. Over an area of about 130 acres the volume of magnesite was estimated to be from $\frac{1}{2}$ to $\frac{1}{3}$ of the total rock volume. Over an area of 1,140 acres, the volume was reckoned to be from $\frac{1}{8}$th to $\frac{1}{10}$th. Of the quantity present in the thin veins and patches in the rest of the area, no opinion has been expressed. The reserves of magnesite in the Chalk hills may be regarded as, humanly speaking, unlimited. The richest portions rise in hillocks some 140 feet above the level of the plains. According to Sir Thomas Holland's view of the origin of this mineral, its formation is not a mere superficial phenomenon, and it may be expected to extend to considerable depths. Dr. J. Coggin Brown[1] describes the compact vein magnesite of India as a hard, white, brittle mineral, closely resembling unglazed porcelain and breaking with a conchoidal fracture; its crystalline structure is not visible to the naked eye.

Through the enterprise of Mr. H. G. Turner, the Magnesite Syndicate, Limited, was formed to develop the deposits. A paper by Mr. H. H. Dains[2] demonstrated the high quality of the material obtainable, the percentage of magnesium carbonate in ordinary samples being from 96 to 97 and in picked samples 99. The following analyses have been made on fair samples :—

	Blount.	Dains.	Pattison (cargo sample).	Ferguson. 1	Ferguson. 2
Silica	0·22	0·29	1·17	0·31	1·70
Iron oxide } Alumina }	0·30	0·65	0·14	0·40	0·65
				1·10	0·10
Manganese oxide	..	0·20	0·06	..	..
Lime	*nil*	0·83	0·78	..	..
Magnesium oxide	47·35	46·42	46·28	97·80	97·40
Carbon dioxide	51·44	50·71	50·10		
Water	0·27	0·16	1·30	0·60	traces
Sulphuric acid	..	..	0·03	..	..
Phosphoric acid	..	..	0·01	..	..
TOTAL	99·58	99·26	99·87	100·06(*a*)	99·85
Magnesium carbonate	98·79	97·13	96·34	97·80	97·40

(*a*) Including 0·85 calcium carbonate.

[1] Bull. Indian Industries and Labour, No. 3, p. 2 (1921).

[2] 'The Indian Magnesite Industry.' *Journ. Soc. Chem. Industry*, XXVIII, p. 503 (1909).

The mineral is won by open quarrying operations and is calcined on the spot to produce (*a*) lightly calcined or caustic magnesia, obtained at a temperature of about 800° C., and (*b*) dead-burnt, sintered, or shrunk magnesia, obtained by calcination at about 1700° C. Roughly speaking 2 tons of the crude ore produce a little less than 1 ton of caustic magnesia, while about 2½ tons are requisite for the manufacture of 1 ton of dead-burnt magnesia. The following is a statement of average analysis kindly supplied by the Magnesite Syndicate, Limited:—

	Lightly calcined magnesite.	Crude magnesite.	Dead-burnt magnesite.
	Per cent.	Per cent.	Per cent.
Silica	4·12	2·21	3·59
Iron oxide and alumina	0·33	0·24	1·07
Lime	1·25	0·96	1·02
Magnesia	92·46	46·04	92·13
Loss on ignition	1·84	50·27	0·15
Moisture	..	0·28	..
	100·00	100·00	100·00

The following table shows the amount of magnesia manufactured during 1924-28 :—

	Tons.
1924	11,026
1925	13,224
1926	10,203
1927	9,852
1928	8,993

Experiments made on a considerable scale on behalf of Mr. H. G. Turner[1] showed that when highly heated in an electric furnace the Salem magesite yields a hard dense crystalline mass of the greatest refractory quality.

Uses of magnesite.

Magnesite has many applications, of which its use as a refractory material is the most important. Carbon dioxide in the liquid form has not so far been recovered from the Salem deposits in India. The question is

[1] *Journ. Iron and Steel Inst.*, No. 1 of 1904, pp. 498-99.

largely one of fuel, freights and markets. Salem is some 200 miles from Madras, and the transport of liquid carbon dioxide would involve freight both ways on heavy steel cylinders. The manufacture of solid carbon dioxide requires an elaborate plant and considerable power.

Of the two commercial varieties of magnesite, the caustic or calcined, which should contain about 94 per cent. of magnesia and carbon di-oxide, 'slacks' when exposed to the air. Before the War, practically the whole of the calcined magnesia of Salem was shipped to Europe for use in the preparation of 'oxy-chloride' or 'Sorel' cement, used in the manufacture of artificial stone, floorings, fire-proof partitions, abrasive wheels, tiles, etc. This cement is formed by mixing caustic magnesia with a solution of magnesium chloride and will carry up to 20 parts of sand for one of magnesia. Owing to the scarcity of European supplies during the War, large quantities of magnesite, in the years 1916-17, were shipped to the United Kingdom from Salem. The attached Table 52 shows the Indian production during the period under review. The average annual production during 1919-23 amounted to 18,039 tons, valued at Rs. 2,15,788; during 1924-28 it rose to 25,717 tons valued at Rs. 2,90,376, with a record production in 1926 of 30,461 tons valued at Rs. 3,54,355.

Dead-burnt magnesia contains less than ½ per cent. carbon dioxide, and should average at least 87 or 88 per cent. of magnesium oxide. The Indian material is always considerably higher in grade. The most objectionable impurity is lime, and here again the Indian commodity excels. The dead-burnt form is a very inert material not easily affected even by extreme heat. Its main use is as a refractory lining for steel furnaces, and in this way the magnesite industry is closely bound up with that of iron and steel. In the basic open-hearth process, about 6 lbs. of magnesite are required for every ton of steel made. Something like 90 per cent. of the total output of magnesite is employed for this purpose alone in the United States. Refractory magnesia is also employed in lead, copper and other smelters. The greater proportion of magnesite produced is utilised in a dead-burnt form.

Other uses for magnesite are the preparation of medicinal compounds, and the manufacture of certain varieties of vitreous por-

celain, of fire-resisting paints, of non-conducting materials for steam-pipe and boiler laggings, and of sulphite paper pulp.

The chief competing sources of supply are Austria, the United States and Greece. The Austrian material, with its higher iron-content, makes a satisfactory lining for steel furnaces, and is, for this reason, in demand by the iron and steel industry. The world's requirements of dead-burnt material are, in fact, met mostly by Austria. Greece produces more calcined magnesia than any other country, and supplies most of the needs of Europe. The Indian material approaches closer to the Grecian type than to the Austrian, and before and after the War the Indian exports have been required more for the manufacture of cements and similar products than for refractory linings. During the War, ferric oxide was added to the Indian magnesite in order to produce a dead-burnt commodity suitable for metallurgical purposes; this plan deserves further investigation. There are immense stores of the double chloride of potassium and magnesium known as carnallite in the saline deposits of Stassfurt in Prussia, and several processes have been patented for utilising the waste magnesium chloride liquor obtained as a by-product in the manufacture of calcium chloride. Magnesium oxide is also obtained from dolomite by calcination at 900° C. followed by lixiviation with ammonium chloride and potassium chloride.

The greatest consumer of magnesite is the United States, and a large percentage of the Indian exports go to that country; 58 per cent. of India's production, for instance, corresponding to 17,200 tons of the crude mineral, were imported into the States in 1925. The United States possess large deposits of their own in Washington where it is dead-burnt, and much smaller deposits in California where the material is practically all lightly calcined. In November, 1927, the import duty on magnesite into the United States of America was raised from 14 to 21 per cent., and this has naturally had its effect upon the Indian trade. As the world's supplies of magnesite are, from a practical point of view, far greater than the demand is ever likely to be, its successful development is largely a matter of geographical position and available markets. A demand in this country for artificial stone products in the form of flooring. tiles, partitions, etc., would stimulate an industry capable of large expansion.

Magnesite is known to occur at several other places in southern

TABLE 52.—*Production of Magnesite during the years 1924 to 1928.*

	1924		1925		1926		1927		1928		AVERAGE.	
	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*
	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*
***Madras*—**												
Salem .	24,427	*2,93,124*	29,620	*4,14,680*	28,676	*3,41,925*	16,966	*2,02,656*	22,542	*1,41,742*	24,446	*2,78,825*
Mysore .	34	(*a*)	..	..	1,785	*12,430*	2,672	*26,682*	1,864	*18,640*	1,271	*11,650*
TOTAL .	**24,461**	*2,93,124*	**29,620**	*4,14,680*	**30,461**	*3,54,355*	**19,638**	*2,29,338*	**24,406**	*1,60,382*	**25,717**	*2,90,376*
Total value in Sterling.	..	*£21,088* (£1 = Rs. 13·9)	..	*£31,179* (£1 = Rs. 13·3)	..	*£26,444* (£1 = Rs. 13·4)	..	*£17,115* (£1 = Rs. 13·4)	..	*£11,969* (£1 = Rs. 13·4)	..	*£21,559*

(*a*) Not available.

India, always as veins traversing peridotites, for example at Seringala in Coorg, on the Cauvery above Fraserpet, in other parts of the Salem district,[1] in the Trichinopoly district, and in the Hassan and Mysore districts of Mysore.[2] In 1923, the Tata Iron and Steel Company acquired magnesite properties in the Mysore district with a view to producing refractory materials for their furnaces at Sakchi. The output in the Mysore state amounted to 4,114 tons in 1919, 3,046 tons in 1920 and 2,865 tons in 1921. The production declined to 856 tons in 1922, and 100 tons in 1923, the decrease being due to the temporary closing down of the mines worked by the Tata Iron and Steel Company, Limited. These mines were re-opened during the quinquennium under report and produced in 1924 34 tons, in 1925 *nil*, in 1926 1,785 tons, in 1927 2,672 tons and in 1928 1,864 tons. The quantities used by this firm at their Jamshedpur works were 633 tons in 1924, 850 tons in 1925 and 548 tons in 1926; since then they have been using imported dead-burnt magnesite and magnesite bricks. According to Mr. A. Ghose large quantities of magnesite, although of inferior quality, occur in association with the steatite deposits of Muddavaram and Musila Cheruvu in the Karnul district (see page 438).

Other occurrences.

Manganese.

[L. L. FERMOR.]

An earlier review records the rapid development of the manganese-quarrying industry in India during the early years of the present century, the zenith being reached in 1907 with an output of 902,291 tons of ore. Since 1905, the industry has maintained a position of comparative stability with an average annual production of 712,797 tons during the pre-war quinquennial period 1909 to 1913. In 1908, India took the lead amongst the world's producers of manganese-ore, hitherto held by Russia, who, however, resumed this lead in 1912 to 1915. The next quinquennial period, 1914-1918, coincided approximately with the period of the war, and was marked by controlled and re-

Progress of the industry.

[1] W. King and R. B. Foote; *Mem. Geol. Surv. Ind.*, IV, pp. 318—324.

[2] A. Primrose; *Rec. Mysore Geol. Dept.* III, p. 239; IV, p. 178. V. S. Sambasiva Iyer; *op. cit.*, p. 61. Annual Reports of the Chief Inspector of Mines in Mysore.

stricted exports, the control being due to the necessity of ensuring that a mineral of such importance to the iron and steel industry should not reach enemy countries either directly as ore or in the form of alloys, iron, or steel, whilst the restrictions were due to the well-known shortage of shipping. In spite of these adverse factors the Indian production during the quinquennium 1914-1918 averaged 577,457 tons annually; but the exports for the official years 1914-15 to 1918-19 averaged only 491,558 tons, with a resultant accumulation in India during the period of over 300,000 tons of stocks, after allowing for ore railed to Sakchi and Kulti for use in the Indian iron and steel industry, this accumulation being due in part to the acute shortage of shipping during 1917 and 1918. During the post-war quinquennium, 1919-1923, the Indian production averaged 624,635 tons annually, whilst the exports during the official years 1919-20 to 1923-24 averaged 681,972 tons, the excess of exports over production indicating a reduction of stocks to the extent of nearly 400,000 tons during the period, after allowing for ore railed to Tatanagar, Kulti, and Burnpur, for use in the iron and steel industry of India. This increase in both production and exports as compared with the war period was not, however, due to a return to pre-war conditions, but marks the balance of beneficial factors in favour of India.

During the quinquennium 1924-28, the Indian production has averaged 953,039 tons, whilst the exports during the years 1924-25 to 1928-29 have averaged 759,104 tons, with a resultant accumulation of over 780,000 tons of stocks, after allowing for consumption by the Indian iron and steel industries. Nevertheless, both production and exports were much in excess of the figures for the previous quinquennium, and these increases, in spite of increasing competition with supplies from other countries, must be taken as a measure of a world's iron and steel industry expanding with a return to relatively normal conditions.

In the previous review, each year of the quinquennium was discussed separately. For the quinquennium now under review this is unnecessary, because, with a gradual return to relatively normal conditions, the factors affecting the prosperity of the manganese industry have, on the whole, varied continuously in one direction. During the quinquennium the world's output of pig iron and ferro-alloys has increased continuously from 65·8 million tons in 1924, to 86·8 million tons in 1928: the output of steel has in-

creased from 75·0 million tons in 1924, to 108·2 million tons in 1928: whilst the world's output of manganese-ore has increased from 2,109,354 tons in 1924, to 3,323,442 tons in 1927, with a decrease to about 2,925,000 tons in 1928, the Indian output at the same time increasing from 803,006 tons in 1924, to 1,129,353 tons in 1927, and falling to 978,449 tons in 1928. The world's data for 1928 are not yet fully available, but the estimated total given above is sufficiently close to the truth to show that in 1928 there must have been a small decline parallel with the fall in the Indian manganese-ore output for 1928. Since the rate of increase in the world's manganese-ore production from 1924 to 1927 was much greater than the rate of increase in the world's production of pig iron and steel, it is not surprising that the quinquennium showed a steady fall in the market price of manganese-ore c.i.f. U. K. ports from 22·9 pence per unit in 1924, to 17·0 pence in 1928. There was also a continuous fall in the average freight rates per ton of manganese-ore from Calcutta and Bombay to United Kingdom ports from £1 2*s.* 8*d.* in 1924, to £0 17*s.* 5*d.* in 1928, so that the average f.o.b. price Indian ports fell from 16·9 pence to 12·8 pence per unit for the same years. The increase in the manganese output was not proportionately as great as that of the world as a whole, so that the Indian proportion of the total fell from 44 per cent. in the previous quinquennium to a figure varying between 33 and 37 per cent. in the quenquennium under review. Moreover, in spite of the large increase in actual production, as distinguished from proportionate production, there was an actual decrease in the amount of ore exported from India, amounting to some 286,000 tons, as compared with the previous quinquennium. The position was not complicated by such large variations in the exchange value of the rupee as marked the previous quinquennium, the range being from 1*s.* 5¼*d.* in 1924, to 1*s.* $6\frac{1}{32}$*d.* in 1925, since when the annual average exchange value of the rupee has remained slightly below 1*s.* 6*d.* The data discussed above are summarised in Table 53.

In the previous review, after discussing the equivalent data, it was noted that the quinquennial period closed with great activity prevalent with many deposits of lower grade ore being worked at a profit after a period of stagnation. The reverse applies to the quinquennial period now under review; for with falling prices and world over-production the period ended with decreasing business

and decreasing profit for Indian producers, leading to curtailment of production, and a search for means of reducing costs, which has already led to requests for reduced railway freights from the mines to the ports.

Of foreign producers, Russia occupied the leading position up to 1907, and in 1912 and 1913 : but subsequently the circumstances of war and, later, internal troubles caused the practical stoppage of the industry, so that production fell from 1,234,900 tons in 1913, to 56,200 tons in 1919, since when the industry has been slowly recovering, so that 407,401 tons were exported from Russia, including Georgia, during 1923. In 1925, the Soviet Government granted a 20 years' concession over the Georgian manganese-ore deposits to Messrs. W. A. Harriman & Co. of New York. The agreement stipulated for expenditure by the lessees on the improvement of the mines, railways and ports, a payment of royalty of $3 per ton, and the shipment of 600,000 tons of manganese-ore a year from Poti. The royalty was subsequently reduced to a minimum of $1·50 per ton, with a sliding scale based on world prices and ocean freight rates, and a limit was placed on the output of the Nikopol mines. In 1928, the Harriman Group, operating under the name of the Georgian Manganese Co., withdrew, the Soviet Government giving bonds in repayment of money invested by the Americans, and as far as is known at present, it is the intention of the Soviet Government to retain and operate the mines. The failure of the American enterprise has been variously ascribed to the fall in manganese prices, high royalties, labour difficulties, and competition from the Nikopol district. As a result of the improvement of transport facilities and in the methods of work, including the installation of up-to-date washing plants introduced by the Americans, the output from Russia and Georgia rose from 420,084 tons in 1924, to 1,012,362 tons in 1926, since when production has fallen to 830,516 tons in 1927, and 722,814 tons in 1928. These figures are in terms of washed ore, except for the small production from the Urals, which is crude ore.

The disappearance of Russia from allied markets during the war was not of very serious moment to the Allies, as it coincided with the isolation of one of the chief consumers of the world's supplies

TABLE 53.—*Worlds' production of pig-iron, steel & manganese-ore,* 1913-28, *with prices, freights and rates of exchange.*

Year.	Iron and steel industry—World's production.		Manganese industry.							
	Pig-iron and ferro-alloys.	Steel.	World's production.	Indian production.	India's percentage of total.	Average price per unit of manganese c.i.f. U. K. ports.	Average freights per ton from Calcutta and Bombay to U. K. ports.	Corresponding price per unit f.o b. Indian ports.	Indian exports: official years.	Average exchange value of the rupee.
	Millions of tons.	Millions of tons.	Long tons.	Long tons.	Per cent.	*Pence.*	£. *s.* *d.*	*Pence.*	Long tons.	
1913	77·5	74·8	2,284,203	815,047	35·7	11·12	0 19 $5\frac{1}{2}$	6·15	804,796	$14\frac{3}{16}$ to $13\frac{29}{32}$
1914	59·1	59·4	1,841,479	682,898	37·1	10·17	0 17 9	5·75	506,982	$14\frac{3}{32}$ to $13\frac{29}{32}$
1915	59·4	65·0	1,393,479	450,416	32·3	20·17	2 1 6	9·6	473,893	$14\frac{1}{16}$ to $13\frac{13}{16}$
1916	72·4	76·7	1,613,050	645,204	40·0	30·7	4 1 8	10·5	652,199	$14\frac{1}{32}$ to 14
1917	65·0	80·3	1,863,549	590,813	31·7	37·7	5 11 8	10·3	437,655	$14\frac{31}{32}$ to $14\frac{1}{32}$
1918	64·4	75·4	1,751,698	517,953	29·6	42·5	6 3 $0\frac{1}{2}$	12·37	387,061	1 $5\frac{11}{16}$
1919	50·9	56·2	1,163,918	537,995	46·2	29·1	3 11 0	11·96	382,116	1 $8\frac{27}{32}$
1920	60·4	68·9	1,718,689	736,439	42·8	45·5	4 9 4	23·46	805,839	2 $0\frac{1}{16}$
1921	36·5	41·1	1,199,490	679,286	46·6	17·6	1 5 0	11·00	530,371	1 $4\frac{1}{32}$
1922	50·1	63·1	1,311,360	474,401	36·2	13·9	0 19 2	8·70	877,194	1 $3\frac{19}{32}$
1923	67·8	75·5	1,680,434	695,055	41·4	21·2	1 1 4	15·48	814,342	1 $4\frac{9}{32}$
1924	65·8	75·0	2,109,354	803,006	38·1	22·9	1 2 8	16·56	639,210	1 $5\frac{1}{4}$
1925	75·7	88·8	2,657,447	839,461	31·6	21·6	1 0 11	15·98	564,225	1 $6\frac{1}{32}$
1926	77·8	91·5	3,184,382	1,014,928	31·9	18·4	1 0 3	12·94	536,214	1 $5\frac{15}{16}$
1927	85·5	100·1	3,323,442	1,129,353	33·9	18·1	0 19 5	13·44	703,949	1 $5\frac{29}{32}$
1928	86·8	108·2	2,923,424	978,449	33·4	17·0	0 17 5	12·82	680,938	1 $5\frac{31}{32}$

of manganese-ore, namely Germany, who before the war imported large quantities from both India and Russia. Such shortage as resulted was felt chiefly in the United States, owing partly to the difficulty of arranging shipping from India, and led to a great development in the manganese industry of Brazil, which, as will be seen from fig. 13, rose from third to second place amongst the world's producers, concurrently with India's resumption of first place. The exports of Brazil were taken almost entirely by the United States, not only to replace former imports from Russia and India, but also to balance a great reduction in the imports of ferro-manganese. On account, however, of the great increase in the activity of the American iron and steel industry for the provision of munitions of war, supplies of manganese-ore were still inadequate, with the result that all known occurrences of manganese-ore in the United States of America were investigated, of whatever grade, so that the output of manganese-ores containing 40 per cent. manganese or over rose from 2,635 tons in 1914, to 129,405 tons in 1917, and of ores containing over 35 per cent. manganese to 305,869 tons in 1918. At the same time the output in the United States of America of ores carrying less than the above percentages of manganese rose from 98,265 long tons in 1914, to 1,170,462 long tons in 1918. To allow for the use of these lower grade ores not only was the composition of standard ferro-manganese in the States reduced from 80 per cent. to 70 per cent. manganese, but many American smelters had to adapt their practice to the use of spiegeleisen in place of ferro-manganese.

In the review for 1914-1918 it was suggested that the great increase in the American manganese industry would not prove to be permanent as it had taken place under the stimulus of restricted supplies and high prices. This, in fact, proved to be the case, and by 1922, the output of ore carrying 35 per cent. of manganese or over fell to 13,404 tons. During the present quinquennium, however, the American production has averaged 58,495 tons annually, with a peak production of 98,324 tons in 1925. This increased production is largely obtained from the State of Montana, partly in the form of carbonate ore and partly as oxide of chemical quality. Nearly all the manganese-ore won in the United States of America during the war was produced at a loss, which Congress decided to make good from the War Minerals Relief Department. To aid

the American manganese industry, Congress in 1922, imposed special import duties on manganese-ore and ferro-manganese. The duty on manganese-ore is 1 cent per pound of metallic manganese for ores containing over 30 per cent. manganese contents. This gives the heavy duty of $ 11·12 per ton on 50 per cent. ore. Indian producers need not, however, be alarmed at this imposition, for the careful report by a sub-committee specially appointed by the Mining and Metallurgical Society of America shows that America has only 1,400,000 tons of high-grade ore (41·30 per cent. of manganese), and, in fact, it is suggested that the only effect of this tariff will be increased costs to the American steel industry of 5 million to 10 million dollars annually. A small portion of the increased production from 1923 to 1928 may be attributed to the effects of the tariff. The major portion is, however, due to the output of carbonate ores and chemical ores from Montana already referred to. These ores are of high enough grade to be produced even without the aid of the tariff.

As was anticipated in the review for 1914-1918, there was not, on the termination of the War, a parallel set-back to the Brazilian manganese industry, which has remained on a permanently increased scale, and consequently a portion of the post-war imports of Brazilian ore into America has been at the expense of India. The average annual exports of Indian ore to the United States of America before the war was 123,060 tons over a 10-year period: the average exports during the war quinquennium was 49,923 tons, whilst during the post-war quinquennium they recovered to 65,505 tons, and during the quinquennium under review to 73,959 tons. With the growth of the American steel industry, it might have been anticipated that India would again secure the same volume of exports to the United States; but, with the entry of the Gold Coast into the industry and the steps being taken to develop a large manganese industry in South Africa, as well as the Soviet methods of working manganese in Russia, this now seems less likely.

Although the Indian manganese industry has reached a position of comparative stability, it is of course subject to variations in prosperity, as is illustrated graphically by the fluctuations in production recorded in fig. 5, page 21. On comparing this diagram with the curves of the world's production of pig-iron and steel shown

in figure 12[1], it is seen that the variations in the activity of the Indian manganese industry are to be correlated with variations in the activity of the iron and steel industry. In the previous review it was pointed out that the maxima of manganese-ore production coincide with maxima of steel production, whilst the minima lag one year behind. This lag means, of course, overproduction during years of lessened demand, with resultant accumulation of stocks. The rule was not, however, followed in 1919, for difficulty in securing sufficient ocean shipping caused the minimum of production of manganese-ore to precede in 1918, the minimum of production of steel of 1919. The rule was, however, again complied with at the next minimum when the steel minimum occurred in 1921, and the Indian manganese minimum in 1922. In 1927, the Indian manganese maximum instead of coinciding with the steel maximum for the same year has been followed by an increased steel production in 1928, which, in view of the recent slump in the United States, will probably prove to be a maximum.

The varying demands of the steel trade make their effect felt on the manganese industry in part through corresponding variations in the price of manganese-ore, and it is interesting therefore to compare the curves of the world's production of iron and steel forming the lower part of figure 12 with the curves showing the price of manganese-ore forming the upper part of the same figure. The two sets of curves have a tendency to move in close sympathy, but the very sharp rise in the curve of prices since 1914, and the sudden fall in 1921-22, indicates the introduction of another factor into the problem besides the activity of the steel trade. This factor is, of course, the excessively high freights that prevailed during the war and for two years after on account of the shortage of shipping. The consequence is that the rapid rise in the curve of market price of manganese-ore cannot be taken as the measure of a corresponding increase in the profits accruing to the manganese industry of India. The sharp rise in 1923, coming to a peak in 1924, is,

[1] The crossing of the curves for pig-iron and steel in 1914 is not an error, but is due to the increasing quantity of steel scrap that is used in the manufacture of steel. The curves indicate that some decades were required for the accumulation in the world of a sufficient capital stock of steel for the wastage therefrom, when returned to the smelters, to produce the effect shown. The curves were due to cross in any case in 1914, but the war with its accompanying greatly increased wastage has accentuated the difference. The curves indicate also that the extra wastage of metals due to war is not as great as at first seems to be the case, owing to the ability of modern industry to utilise scrap metal.

however, practically independent of freight charges. From 1924 onwards, the curves of market price of manganese-ore and production of steel have moved in opposite directions due to overproduction of manganese-ore, relative even to the increased demand from the steel industry.

Prices.

In Table 54 is given a statement of the prices of first-grade manganese-ore c.i.f. United Kingdom ports during the quinquennium. The quotations have been taken from the *Mining Magazine.* The mean prices shown in the third column have been obtained by averaging the quotations for the twelve months of each year. In figure 12 these prices are compared with the world's production of pig-iron and steel.[1]

As already noticed the steep rise in the curve of prices during 1915 to 1917, and the sharp fall in 1920 and 1921, are largely due to enhanced freights during the war period: consequently, in order to discover the extent to which the Indian manganese industry may have benefited by the increased prices it is necessary to eliminate the portions representing freight and reduce to f.o.b. prices. This is desirable also, because, for the same reason, it was found necessary during the war to base the sliding scale of royalties applied in the Central Provinces and Bombay on f.o.b. prices instead of the c.i.f. prices formerly used. The following table gives the necessary data and reveals that although the price of manganese-ore during the war c.i.f. at United Kingdom ports increased by some 100 to 320 per cent., the effective increase to the manganese industry of India was only some 60 to 100 per cent.

Subsequent to the war, however, prices rose in 1920, to a still higher level than at any time during the war in spite of a considerable fall in ocean freights. The result was that exports of manganese-ore during 1920-21, amounted to more than double the tonnage exported during 1919-20, yielding a very substantial profit to the Indian manganese industry, in spite of the high rupee-sterling exchange rates prevailing in 1920.

[1] Strictly speaking the portion of the above curves representing the war period should give the world's production exclusive of those countries—Austria, Hungary, Belgium, Germany, and Russia—that were isolated from the world's markets. Such reduced figures give curves very similar to those actually shown, but faulted for the period 1914 to 1918 to a position about 20 million tons lower in the diagram.

TABLE 54.—*Variation in the price of first-grade Manganese-ore c.i.f. at United Kingdom ports.*

Date.	Price per unit in pence.	Mean price for year in pence.
January 1924	22 —23	22·9
July 1924	23	
January 1925	21½—22	21·6
July 1925	21	
January 1926	21	18·4
July 1926	17½—18	
January 1927	19¾—20	18·1
July 1927	17	
January 1928	16½—18½	17·0
July 1928	16 —18	
January 1929	16	14·0
July 1929	14	
January 1930	13¾	..

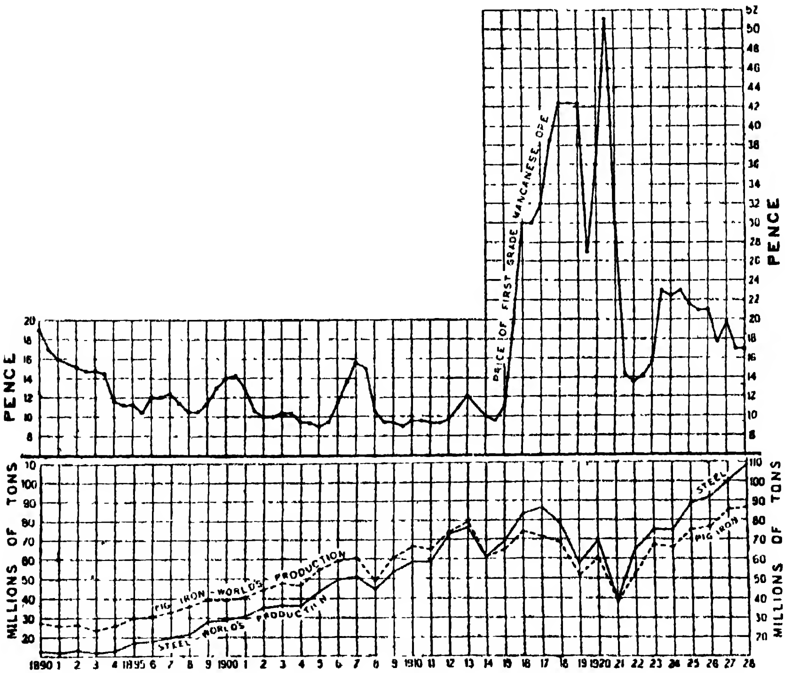

FIG. 12.—*Variation in the prices of Manganese-ore at United Kingdom ports since 1890, compared with the world's production of Pig-iron and Steel.*

TABLE 55.—*Comparison of ocean freights with c.i.f. and f.o.b. prices of Indian Manganese-ore.*

—	Average freights per ton from Calcutta and Bombay to U.K. ports.	Average price of 1st grade ore per unit c.i.f. U.K. ports.	Value per ton 50% ore c.i.f. U.K. ports.	Value per ton f.o.b. Indian ports.[1]	Corresponding price per unit f.o.b Indian ports.
	£ *s.* *d.*	*Pence.*	£ *s.* *d.*	£ *s.* *d.*	*Pence.*
1914	0 17 9	10·17	2 2 4½	1 3 1½	5·75
1915	2 1 6	20·17	4 4 0½	2 0 0½	9·6
1916	4 1 8	30·7	6 7 11	2 3 9	10·5
1917	5 11 8	37·7	7 17 1	2 2 11	10·3
1918	6 3 0½	42·5	8 17 1	2 11 6½	12·37
1919	3 11 0	29·6	6 3 4	2 9 10	11·96
1920	4 9 4	45·5	9 9 7	4 17 9	23·46
1921	1 5 0	17·6	3 13 4	2 5 10	11·00
1922	0 19 2	13·9	2 17 11	1 16 3	8·70
1923	1 1 4	21·2	4 8 4	3 4 6	15·48
1924	1 2 8	22·9	4 15 5	3 10 3	16·86
1925	1 0 11	21·6	4 10 0	3 6 7	15·98
1926	1 0 3	18·4	3 16 8	2 13 11	12·94
1927	0 19 5	18·1	3 15 5	2 13 6	12·84
1928	0 17 5	17·0	3 10 10	2 10 11	12·22

[1] Obtained by deducting from c i.f. values not only ocean freights, but also destination charges taken at 2*s*. 6*d*. per ton.

During the quinquennium now under review, the freights have fallen to pre-war values, and, in consequence, as the c.i.f. prices of manganese-ore, though steadily falling, were even by 1928 still considerably in excess of the average pre-war values, the f.o.b. prices were also substantially in excess of pre-war figures. On page 192 it is shown that the post-war lower governing price of manganese is likely to be 13 pence. On the basis of a freight of 17*s*. 6*d*. and ore containing 50 per cent. manganese the corresponding f.o.b. lower governing price would be 4·2*d*. lower or 8·8*d*. The extent to which the f.o.b. price in 1928, was still above this figure may be taken as a measure of the profit then obtainable by the industry. A fall in the c.i.f. price from 17 pence to 13 pence, or of the f.o.b. price from 12·8 to 8·8*d*. would extinguish the profit for many producers.

During the period now under review the following limited liability companies were at work. Most of them were formed during the years 1905 to 1907; but the Vizianagram Mining Co. was floated in 1895, and the Tirody Manganese Ore Co. in 1928.

Companies working.

Bombay—

1. The Shivrajpur Syndicate.
2. The Bamankua Manganese Company.

Central Provinces—

1. The Central India Mining Company.
2. The Indian Manganese Company.
3. The Central Provinces Manganese Ore Company (name changed from Central Provinces Prospecting Syndicate in 1924).
4. The Netra Manganese Company.
5. The Tirody Manganese Ore Co. (acquired the properties of D. Laxminarayan in 1926).

Madras—

1. Vizianagram Mining Company.
2. The General Sandur Mining Company.

Mysore—

1. The United Steel Companies (formerly the Workington Iron and Steel Company).
2. The Peninsular Minerals Co. of Mysore.

Other prominent workers during this quinquennium have been :—

The Carnegie Steel Company : Central Provinces.

The Tata Iron and Steel Company : Central Provinces.

B. P. Byramjee & Company : Central Provinces.

D. Laxminarayan : Central Provinces.

Nagpur Manganese Mining Syndicate : Central Provinces.

Rai Bahadur Bansilal Abirchand Mining Syndicate : Central Provinces.

The New Gangpur Mining Syndicate : Bihar and Orissa.

Bird and Company : Bihar and Orissa.

Production.

Table 56 shows the production from each district, state and province during the past five years, and fig. 5 on page 21 shows the progress of the industry since its beginning. From this it will be seen that the Central Provinces is by far the most important province as a producer of manganese. The figures in this table represent, except in a few cases, quantities of ore won or raised, and not of ore railed.

TABLE 56.—*Production of Manganese-ore in India*

—	Bihar and Orissa.				
	Gangpur.	Keonjhar.	Sambalpur.	Singhbhum.	Total.
	Tons.	Tons.	Tons.	Tons.	Tons.
1924 . . .	16,481	20,803	..	797	38,081
1925 . . .	9,617	26,330	703	195	36,845
1926 . . .	10,379	23,810	..	2,473	36,662
1927 . . .	7,960	51,115	..	9,970	69,045
1928 . . .	6,379	72,411	..	23,199	101,989
TOTAL .	50,816	194,469	703	36,634	282,622
Provincial average	..	..	..	..	*56,524*
Provincial average 1919—23.	..	..	..	..	20,453

—	Central Provinces.							
	Balaghat.	Bhandara.	Chhindwara.	Jubbulpore.	Nagpur.	Total.	Bellary.	Kurnool.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1924 . . .	270,151	74,869	32,715	1,850	204,521	584,106	5,424	390
1925. . .	262,450	104,398	37,109	1,901	216,484	622,342	5,419	6
1926. . .	336,579	152,858	42,242	100	229,586	761,365	8,853	..
1927. . .	313,556	130,211	47,264	181	252,637	743,849	6,004	..
1928. . .	248,497	89,059	37,069	..	216,509	591,134	5,257	..
TOTAL .	1,431,233	551,395	196,399	4,032	1,119,737	3,302,796	30,957	396
Provincial average	..	..	..	..	..	*660,559*	..	..
Provincial average 1919—23.	..	..	..	..	..	505,402	..	..

during the five years 1924 to 1928.

Bombay.					Central India.
Chhota Udepur.	Belgaum.	Panch Mahals.	North Kanara.	Total.	Jhabua.
Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
10,142	..	46,401	..	56,543	2,263
6,805	3,604	52,069	..	62,478	5,206
10,000	4,290	57,325	2,000	73,615	7,969
11,729	4,515	78,802	4,005	99,051	10,510
7,267	1,603	63,040	3,601	75,511	3,835
45,943	14,012	297,637	9,606	367,198	27,783
..	..	..	..	*73,440*	*5,557*
..	..	..	..	57,295	..

Madras.			Mysore.				Totals for whole of India.	
Sandur State.	Vizagapatam.	Total.	Chitaldrug.	Shimoga.	Tumkur.	Total.		
Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Statute Tons.	Metric Tons.
43,809	31,811	81,434	1,556	36,206	2,817	40,579	803,006	*815,854*
52,576	26,909	84,910	2,494	24,572	2,614	29,680	839,461	*852,892*
77,327	21,698	107,878	1,599	23,032	2,808	27,439	1,014,928	*1,031,167*
138,196	31,992	176,192	4,021	23,658	3,027	30,706	1,129,353	*1,147,423*
139,801	29,094	174,152	1,907	27,094	1,927	31,828	978,449	*994,104*
451,709	141,504	624,566	11,577	135,462	13,193	160,232	4,765,197	*4,841,449*
..	..	*124,913*	..	..	..	*32,046*	953,039	*968,288*
..	..	19,782	..	..	..	21,708	624,635	634,623

Comparing this quinquennium with the previous five years, it will be seen that the average annual production of manganese-ore for the whole of India shows a large increase from 624,635 to 953,039 tons, which is 33·7 per cent. greater than the quinquennial average for the period 1909-1913, the period of previous greatest production. In each of the years 1926 and 1927 the production exceeded one million tons, that for 1927, namely 1,129,353 tons, being the largest production so far recorded from India. The output of Russia, including Georgia, in 1913 was 1,234,900 tons; and in 1926, 1,012,362 tons otherwise there are no other previous records of a year's production of a million tons from any country. The previous maximum production recorded from India was 902,291 tons in 1907. The average increase recorded during the quinquennium under review over the previous quinquennium was shared by all the provinces, whilst Central India again became a producer, though on a small scale. The average annual increases were in round figures 155,000 tons (30·7 per cent.) from the Central Provinces, 105,000 tons (531 per cent.) from Madras, 36,000 tons (180 per cent.) from Bihar and Orissa, 16,000 tons (28 per cent.) from Bombay, and 10,000 tons (48 per cent.) from Mysore. The increase in the Central Provinces was shared by the districts of Balaghat, Bhandara and Nagpur, but there was a small decrease in the output of the Chhindwara district. The Jubbulpore district was responsible for an output of 4,032 tons during the quinquennium. The huge percentage increase in the output from Madras was due mainly to the resumption of work in Sandur State, but there was also a substantial increase in the Vizagapatam district; whilst the Bellary district became a regular producer for the first time with an average annual production of some 6,000 tons. A small output (396 tons in all) was recorded from Kurnool. The large percentage increase in the output of Bihar and Orissa was in part due to Gangpur State, but was mainly due to Keonjhar State (the initial production was 1,968 tons in 1923), which was responsible for an output rising from 20,000 tons in 1924, to 72,000 tons in 1928. The production of Singhbhum rose also, namely, from 800 tons in 1924, to 23,000 tons in 1928. These large increases from Keonjhar and Singhbhum are due to the opening up by Messrs. Bird & Co. of deposits associated with the iron-ore deposits of those areas. The Bombay increase is largely due to an increase of 23,000 tons annually from the Panch Mahals offset by a decrease of over 11,000 tons annually from Chhota Udepur, but helped by a small annual output from the Belgaum (from 1925) and North Kanara districts (from 1926). Manganese-ore has been produced in the past from Belgaum (1905-

1908 and 1916) but there has been no previous reported output from North Kanara.

The activity of the Indian manganese industry during the past 15 years, and its importance as compared with that of other countries can be seen from Table 57, giving the world's production of manganese-ore for the years 1913 to 1927, and for 1928 as far as available. The figures have been taken chiefly from the reports of the Imperial Institute and are given in long tons.

Production of foreign countries.

From this table it will be seen that for some years the three leading countries producing manganese-ore have been Brazil, India, and Russia. During the pre-war quinquennium, the output, or rather exports, of Brazil sank from a maximum of 249,941 long tons in 1910, to 120,335 tons in 1913, the average annual exports being 186,172 tons. During the same period, the production of India fluctuated between about 650,000 and 830,000 tons, averaging 712,797 long tons, whilst that of Russia rose almost continuously from 565,856 long tons in 1909, to 1,234,900 tons in 1913, with an annual average of 740,906 tons.

During the war quinquennium, the output, or rather exports of Brazil rose from a minimum of 180,679 tons in 1914, to 524,291 tons in 1917, the average annual exports being 374,222 tons. During the same period, the production of India fluctuated between about 450,000 and 680,000 tons, averaging 577,457 tons, whilst that of Russia, including Georgia, fell continuously from 1,234,900 tons in 1913, and 891,400 tons in 1914, to 150,000 tons in 1918, with an annual average for 1914-1918 of 404,000 tons. During the same period, the production of the United States of America rose from 2,635 tons in 1914, to 305,869 tons in 1918, with an annual average of 95,799 tons. In fact, as is shown graphically in Plate 6, the war led ultimately to an almost complete cessation of the Russian manganese industry, to a moderate contraction of that of India, and to a resultant great expansion in the production of manganese-ore in Brazil and the United States of America; so that in 1918, the first three places amongst the world's producers were held by India, Brazil, and the United States of America, in the order named. During the war quinquennium largely increased outputs were forthcoming from some of the other small producers, of which Cuba, Italy, Japan, Spain and Sweden may be mentioned. In addition a multitude of new producers appeared on the scene, of which the Gold Coast and Egypt (Sinai) alone need be mentioned.

TABLE 57.—*World's annual production of*

(Statute

Year.	Austria-Hungary. (a)	Brazil. (b)	China. (b)	Cuba.	Dutch East Indies.	Egypt.	France.	Gold Coast.	India.
1913 .	89,609	(b) 120,335	..	11,406	..	..	7,608	..	815,047
1914 .	28,870	(b) 180,679	..	9,716	..	..	6,290	..	682,898
1915 .	33,513	(b) 284,032	..	9,000	..	..	10,158	..	450,416
1916 .	22,310	(b) 495,044	..	33,120	..	..	10,633	(b) 4,258	645,204
1917 .	136,884	(b) 524,291	..	44,496	..	..	11,408	(b) 31,186	590,813
1918 .	177	(b) 387,066	20	81,966	..	27,064	9,712	(b) 30,292	517,953
1919 .	5,182	(b) 202,419	2,997	(b) 31,212	2,868	47,965	6,903	(b) 35,189	537,995
1920 .	37,161	(b) 446,445	24,923	(b) 22,163	4,112	73,316	10,200	(b) 40,970	736,430
1921 .	56,806	(b) 271,263	25,223	(b) 622	2,059	54,180	1,892	(b) 7,195	679,286
1922 .	43,907	(b) 335,230	18,926	(b) 9,059	2,278	102,469	689	(b) 66,113	474,401
1923 .	70,086	(b) 232,041	27,234	19,320	5,159	130,256	5,897	(b)189,634	695,055
1924 .	98,382	(b) 156,670	37,928	24,903	8,346	(f)147,780	4,920	(b)255,843	803,006
1925 .	106,653	321,836	42,577	23,876	(b) 9,866	79,316	3,939	(b)357,165	839,461
1926 .	127,562	256,420	41,789	(b) 24,256	11,765	119,943	4,520	398,551	1,014,928
1927 .	158,040	269,174	45,617	(b) 127,704	14,727	150,431	2,667	403,187	1,129,353
1928 .	161,240	314,774	42,646	(g) 25,000	(g) 10,000	135,380	3,059	376,913	978,449

(a) Figures for 1913 to 1915 include Bosnia and Herzegovina: for 1916 Bosnia and Herzegovina only: for 1917 exclude Austria: for 1918, 1919, are for Austria only: for 1920, for Austria and Czecho-Slovakia: for 1921, 1922, 1923, 1924, 1927, are for Austria, Czecho-Slovakia and Jugoslavia: for 1925, 1926, for Austria, Czecho-Slovakia, Jugoslavia and Hungary.

(b) Exports.

(c) Georgia only.

(d) Years ended 30th September.

(e) Includes Panama, 10,498 tons.

(f) Includes Costa Rica, 7,163 tons and Argentina, 6,000 tons.

(g) Includes Costa Rica, 9,680 tons and Australia, 8,891 tons.

Manganese-ore during the years 1913 to 1928.

Tons.)

Italy.	Japan.	Rumania.	Russia and Georgia.	Spain.	Sweden.	United Kingdom.	United States.	Other Countries.	World's Total.	Percentage of total produced in India.
1,596	17,755	..	1,234,900	21,247	3,937	5,393	4,048	1,322	2,284,203	35·7
1,022	16,805	..	801,400	12,944	3,584	3,437	2,635	601	1,841,479	37·1
12,375	25,470	..	528,000	14,098	7,485	4,640	9,613	3,770	1,393,479	32·3
17,855	48,547	..	(c) 247,000	13,950	8,751	5,140	31,474	(e) 20,764	1,613,050	40·0
24,138	50,579	..	(c) 201,380	56,550	19,554	9,042	129,405	(f) 32,078	1,863,549	31·7
31,383	56,109	..	(c) 150,000	76,465	16,804	17,456	305,869	(g) 43,862	1,751,698	29·6
30,345	22,523	5,694	56,200	65,614	12,081	12,078	55,322	(h) 31,331	1,163,918	40·2
35,577	5,389	3,315	95,463	20,914	14,086	12,875	94,420	(j) 40,321	1,718,689	42·8
5,025	3,821	2,986	(e) 28,364	19,775	6,145	514	13,531	20,743	1,199,490	50·6
4,619	4,371	5,305	(e) 192,651	25,046	4,438	250	13,404	8,204	1,311,360	36·2
9,451	5,406	12,310	(e) 237,014	28,175	4,964	2,021	31,500	(k) 24,911	1,680,434	41·4
11,902	7,463	6,378	(d) 420,084	20,505	10,706	2,457	56,515	(l) 36,066	2,109,354	38·1
14,747	11,850	5,283	(d) 665,620	35,502	10,768	829	98,324	(m) 30,835	2,657,447	31·6
13,789	14,969	8,221	(d) 1,012,362	44,237	15,017	128	46,258	(n) 29,667	3,184,382	31·9
9,601	27,125	10,205	(d) 830,516	36,288	16,557	1,509	44,741	(o) 46,000	3,323,442	33·9
10,112	17,414	30,778	(r) 722,814	13,488	15,541	235	46,636	(p) 10,000	2,923,424	33·4

(h) Includes Germany, 10,800 tons and Costa Rica, 7,726 tons.
(j) Includes Chile, 11,446 tons.
(k) Includes Germany, 10,080 tons.
(l) Includes Portugal, 6,564 tons.
(m) Includes Chile, 10,887 tons
(n) Includes Chile, 10,473 tons, and Greece, 6,248 tons;
(o) Includes Turkey, 11,219 tons, Greece, 7,955 tons and Chile, 7,567 tons.
(p) Largely estimated.
(q) Estimated.
(r) Excludes Urals.

During the succeeding quinquennium (1919-1923), the Indian production recovered to an average of 624,635 tons, the Brazilian exports fell somewhat to an average of 297,479 tons, whilst the Russian exports averaged some 170,000 tons, probably largely from stocks. During the same quinquennium, the output of the United States of America reverted nearly to the pre-war level, as did that of many other countries, but the production of Egypt rose to 130,256 tons in 1923, and that of the Gold Coast to 139,634 tons in the same year, these two countries then ranking as the 5th and 4th producers respectively. China also became a small regular producer.

In the quinquennium under review the Indian production rose to an average of 953,039 tons, a figure some 50 per cent. higher than the quinquennial average of 1909-1913; the Brazilian average fell still further to 263,675 tons, while the Russian (including Georgian) production rose to 730,279 tons, a figure still below the average for the pre-war quinquennium 1909-1913 (768,269 tons); the average annual production of the Gold Coast rose to 352,232 tons, making it the fourth largest producer of manganese-ore, whilst the production of Egypt, the fifth largest producer, averaged 126,560 tons. The totals shown under Austria-Hungary in Table 57 include the output of Austria, Czecho-Slovakia, Hungary, and Jugo-Slavia, of which that of Czecho-Slovakia is becoming annually more important, rising from 41,377 tons in 1923, to 106,664 tons in 1927, and 97,867 tons in 1928. The Egyptian deposits are in Sinai, only 10 to 15 miles from the port of Abu Zenima, and the total reserves are estimated at 11,848,000 tons, averaging 32·3 per cent. manganese and 25 per cent. iron, the ore being a ferruginous manganese-ore. The ore from the Gold Coast is in part first-grade manganese-ore showing 51 to 52 per cent. manganese, and, as such, it enters into competition with the Indian ore.

Another country that is likely to compete seriously with India in the future is South Africa, where large deposits of first-grade manganese-ore have been discovered near Postmasburg in Griqualand West, a portion of the Cape Province. The deposits occur in two ranges—the Gamagara and Klipfontein ranges—and in the western or Gamagara range they have been followed almost continuously for 30 miles, and there is no doubt that the tonnages of ore available are enormous. The ore is hard and compact like that of the Central Provinces of India, and chemically much of it is said

to be of first-grade quality. It is intended to select the ore to give a product averaging 52 per cent. manganese, 6 per cent. iron, 5 per cent. silica and phosphorus up to 0·1 per cent. To connect Postmasburg with the existing railway system of South Africa, 65 miles of railway are now under construction. The ore is to be railed to Durban for shipment. Plans are being made by the principal manganese company to open up these deposits on a scale sufficient to yield an output of 350,000 tons annually, to be increased substantially as mining facilities are developed and markets secured. Should it prove in practice possible to realise the estimates that have been drawn up of costs of placing the South African manganese-ore c.i.f. at United Kingdom and European ports, then there is no doubt that the South African manganese-ore will become a serious competitor in the world's manganese market. In quality it would prove a serious competitor with the ore from the Central Provinces of India.

It is difficult to forecast the future progress of the manganese industry of Russia. With the termination of the Harriman concession in 1928, the Soviet Government took over the working of the mines, and it is reported that mining has reverted to pre-war methods, that mechanical cleaning plants have been largely abandoned in favour of hand washing, whilst payments are made in paper money produced at the cost of printing, so that the Soviet can afford to sell at any price that leaves a profit after payment of freight and other incidental transport charges. It seems theoretically possible, therefore, that the Russian manganese industry will capture a continuously increasing portion of the world's market for manganese-ore by causing prices to fall to a figure at which it will be unprofitable for most other countries to continue work. There appear, however, to be limiting factors to the indefinite expansion of the Russian manganese industry. One is the method of mining, which, being again largely individual and unorganised, is not likely to result in an indefinite increase of output; another is that the Russian ore needs washing before shipment and is in many cases too small and soft to be used without admixture with harder lump ores of the Central Provinces (or South African) type; a third must be the ultimate difficulty of maintaining uneconomic methods of production. Nevertheless, in estimating the future for Indian manganese-ore, we must assume that the Russian industry will show a further, though not necessarily very great, expansion during

the next quinquennium, and that South Africa will enter the market as a substantial producer.

It may seem rash to attempt to predict the future price of manganese-ore per unit. Nevertheless, it is possible on certain assumptions to indicate the future minimum price of manganese-ore. Before the War the price of manganese was subject to considerable fluctuations, but an inspection of figure 12 will show that the price of first-grade ore never fell below 9*d.* per unit (except momentarily). The reason is that this was the lower limit at which the majority of mines could work at a profit, and at this figure so many producers ceased work or reduced their scale of operations that the price could not fall lower (except momentarily). We may therefore call 9*d.* the *pre-war lower governing price of manganese-ore.* What is the equivalent post-war figure? Apparently all we need is to select a factor representing the post-war cost of supplies and services as compared with pre-war cost and multiply 9*d.* by this figure. Taking the pre-war figure at 100, a good figure for the present cost of supplies and services is considered to be 145. 9*d.* multiplied by 1·45 equals 13*d.* very closely, and we may take 13*d.* as the *post-war lower governing price of manganese.* This should fall only if the post-war cost of supplies and services falls. The post-war lower governing price has already been nearly reached once, *viz.*, in 1922, when the price fell to 13½ pence per unit with an average for the year of 13·9 pence. The effect of these low prices was seen in the low output for 1921-22 (the fall of price began in 1921) with a resultant rebound of both prices and output in 1923. Prices are now again approaching the minimum (they are nominally 14*d.* at the time of writing).

It cannot be regarded as certain, however, that future prices will not fall below 13*d.* One reason is that Russian ore can be produced below this figure owing to the non-economic payment of labour by Soviet Russia. The other is that the promoters of the South African manganese industry anticipated being able to produce at a profit below this figure. The extent to which South African anticipations prove realisable in practice, combined with the extent to which Russian methods of finance can persist, will determine the extent to which the prices of manganese can fall below what would otherwise be its natural minimum, *viz.*, 13*d.* A further fall in the cost of supplies and services would, of course, permit a fall in this natural minimum price.

With the appearance at intervals of new producers it is of interest to trace the extent to which India has maintained her position. During the pre-war quinquennium, India produced 40·8 per cent. of the world's average total annual production of some 1,750,000 tons of manganese-ore; during the war quinquennium, the Indian proportion fell to 34·1 per cent. out of an average total annual production of some 1,690,000 tons, whilst, during the post-war quinquennium, the Indian proportion rose to 43·2 per cent. of the reduced world's output of some 1,445,000 tons annually. During the quinquennium now under review, whilst the Indian production rose to a figure never previously attained, the Indian proportion fell to 33·5 per cent. on account of the increase in the world's total annual output to nearly 2,840,000 tons.

Production of manganiferous iron-ores.

In previous reviews a table has been given of the world's production of manganiferous iron-ores. Data are, however, so scanty that in Table 58 of the present review are given the figures for the United States only. Formerly, all manganiferous ores containing less than 40 per cent. manganese were included, but, since 1918, the line between manganese-ores and manganiferous iron-ores has been drawn at 35 per cent. manganese.[1] The importance of large stores of manganiferous iron-ores to a country poor in manganese-ores proper is shown by the case of the United States, where an insufficiency of imports of manganese-ore during the war was mitigated by a large expansion in the output of indigenous manganiferous iron-ores accompanied by modifications in furnace practice where necessary. In the case of Germany, also, the cessation of imports of manganese-ore from Russia and India was met to a large extent by a greatly increased production of the manganiferous iron-ores of Siegerland,[2] and it is unfortunate, therefore, that the relevant figures are not available for inclusion in the above table. In addition to the United States of America, there is a small production of manganiferous iron-ore in Spain, Algeria, Greece and Italy; further, by the United States of America standards the Egyptian ore (see Table 57) would be classified as manganiferous iron-ore, as also would a very small proportion of the Indian ore.

[1] See p. 205 for a scheme of classification of manganese-ores.

[2] H. C. H. Carpenter; *Nature*, 4-11-15 (p. 257).

TABLE 58.—*United States production of Manganiferous Iron-ores from 1924 to 1928.*

(Long Tons).

Year.	Ores containing from 10 to 35 per cent. Mn.	Ores containing from 5 to 10 per cent. Mn.	Total.
1924	286,470	587,026	**873,496**
1925	267,252	1,153,268	**1,420,520**
1926	364,312	835,412	**1,199,724**
1927	148,291	1,310,127	**1,458,418**
1928	90,711	1,085,401	**1,176,112**

Exports.

For comparison with the annual figures of production of manganese-ore in India, the export figures during the years 1924 to 1928 are given in Table 59 (stated separately for each port). As compared with those for the previous quinquennium these figures show increased exports from Calcutta and Marmagao and decreased exports from Bombay.

TABLE 59.—*Exports of Indian Manganese-ore from 1924 to 1928.*

(Statute Tons.)

Year.	Vizagapatam.	Bombay.	Calcutta.	Marmagao (a)	Yearly Total.
1924 . .	36,600	279,024	342,067	108,758	**766,449**
1925 . .	28,203	311,825	264,170	134,653	**738,851**
1926 . .	9,800	222,371	291,745	89,620	**613,536**
1927 . .	13,910	249,360	418,173	162,378	**843,821**
1928 . .	9,002	270,961	378,604	175,577	**834,144**

(*a*) Figures exclude ore raised in Goa.

From Table 60, giving the total Indian production and exports for the years 1892 to 1929, it will be seen that by the end of 1929, there was an excess of production over exports of over $1\frac{1}{2}$ million tons, of which, however, 417,739 tons is accounted for by railings to Tatanagar, Kulti, and Burnpur, from 1914 to date (from 1911 for Tatanagar) after allowing for ore sold by the Tata Iron and Steel Co. for export; the remainder represents stocks accumulated at the mines and ports and is larger by about 780,000 tons than the surplus recorded in the previous review after allowing for ore railed to the iron works. This increase in stocks is due to the production of each year of the quinquennium being substantially in excess of the exports for the same year. This continuous over-production has accompanied a continuous fall in prices. The logical result should be production during the present quinquennium on a smaller scale than exports.

TABLE 60.—*Comparison of Indian Manganese-ore production with exports.*

(Statute Tons.)

Period.	Ore produced.	Ore exported.	Excess of production over exports.
1892 to 1903 . . .	929,145	..	..
1892-93 to 1903-04 . .	..	916,386	12,759
1904 to 1908 . . .	2,545,718	..	..
1904-05 to 1908-09 . .	..	2,217,596	328,122
1909 to 1913 . . .	3,563,984	..	..
1909-10 to 1913-14 . .	..	3,471,416	92,568
1914 to 1918 . . .	2,887,284	..	..
1914-15 to 1918-19 . .	..	2,457,790	429,494
1919 to 1923 . . .	3,123,176	..	..
1919-20 to 1923-24 . .	..	3,409,862	*—286,686*
1924 to 1928 . . .	4,764,494	..	..
1924-25 to 1928-29 . .	..	3,795,522	968,972
Total .	**17,813,801**	**16,268,572**	**1,545,229**

TABLE 61.—*Distribution of exported Indian Manganese-ore for the years 1924-25 to 1928-29 (a).*

(Statute Tons.)

Year.	Belgium.	Canada.	France.	Germany.	Italy.	Japan.	Netherlands.	Norway.	Sweden.	United Kingdom.	United States of America.	Other countries.	Total recorded export for the Year.
1924-25	203,247	..	147,000	6,050	13,482	250	..	..	..	194,671	72,348	2,162	639,210
1925-26 . .	168,621	..	138,375	30,418	11,925	..	3,010	..	..	155,178	56,698	..	564,225
1926-27 . . .	186,477	5,000	168,366	6,141	7,400	20,510	13,300	..	..	57,720	71,300	..	536,214
1927-28	182,397	..	149,838	14,880	5,650	3,282	15,000	479	1,000	234,223	97,200	..	703,949
1928-29	167,885	..	230,175	20,445	8,975	..	8,001	..	..	166,940	72,250	6,267	680,938
TOTALS (1924-25 to 1928-29).	908,627	5,000	833,754	77,934	47,432	24,042	39,311	479	1,000	808,732	369,796	8,429	3,124,536
TOTALS (1919-20 to 1923-24) .	948,974	..	531,723	27,017	61,622	9,558	75,850	..	2,800	1,224,288	327,529	1,254	3,210,620
TOTALS (1913-14 to 1918-19) .	72,603	..	233,721	14,250	61,025	62,536	..	..	..	1,6807,93	239,616	4,230	2,368,778
TOTALS (1908-9 to 1912-13) .	794,859	..	484,596	33,402	14,400	19,289	93,275	..	..	963,111	610,988	13,618	3,035,530

(*a*) Excludes exports *viâ* Marmagao.

Distribution of Indian manganese-ore exports.

The distribution amongst foreign countries of the manganese-ores exported from India during the quinquennium is shown in Table 61. The figures for the war quinquennium, as compared with the similar data for the pre-war quinquennium showed certain abnormal features. The first feature was the disappearance of Belgium, Germany, Holland, and Austria-Hungary, from the importing countries for the period of the war: the second was the large decrease in the exports to France and the United States: and the third the large increase in the exports to the United Kingdom—1,680,796 tons in the war quinquennium as compared with 966,111 tons during the previous period.

During the post-war quinquennium (1919-20 to 1923-24) the data showed a partial reversion to the pre-war figures, which has been maintained during the quinquennium now under review, except for France, which shows an abnormal increase in imports to 833,754 tons, as compared with her pre-war figure of 484,596 tons. The total imports of Germany, Holland and Belgium (most of which are for consumption in Germany) were 1,025,872 tons against 876,536 tons in the pre-war period. The imports of the United States of America fell to 369,796 tons against 660,988 tons for the pre-war period, whilst those of the United Kingdom fell to 808,732 tons against 966,111 tons for the pre-war period. The net balance was a total of exports from India of 3,124,536 tons during the quinquennium under review against 3,035,530 tons during the pre-war quinquennium.

Labour.

In Vizagapatam and Mysore an adequate supply of labour seems to be easily obtainable, but in the Central Provinces, Central India, the Sandur hills, and other parts, labour has frequently to be imported. To relieve themselves of unnecessary trouble and responsibility the mine managers find it preferable to work through contractors, paying them at a given rate per 1,000 cubic feet of stacked and cleaned ore, and for dead-work at a given rate per 1,000 cubic feet of cavity made in the quarry in the case of soft 'deads,' or per 1,000 cubic feet of waste measured in tubs or stacked in the case of hard 'deads.' The daily rates paid to the coolies by the contractors for an eight

hours' day vary between the following limits in different parts of India[1] :—

	Annas.
Men	6 to 8
Women	3 to 5
Children (over thirteen)	2 to 4

But in the Central Provinces most coolies work on piece-work rates, and if they work reasonably well can earn Re. 1 a day for a man and wife, or say, As. 10 for the man and As. 6 for the woman. Some men, however, earn sums considerably in excess of the above figure.

The average daily number of workers during the past five years is shown in Table 62, the average annual figure being somewhat higher than in any previous quinquennium.

In order to permit of the comparison of the manganese with the coal industry as regards labour, the figures appertaining only to those mines that come under the revised Mines Act, 1923, are given in Table 63. From these figures it is seen that the average number of persons employed daily on the manganese mines under the Act has been 28,779 for an average annual output of 766,185 tons compared with 14,134 persons and an average annual output of 495,255 tons of ore for the previous quinquennial period. The number of tons of ore won annually per person employed has decreased steadily from 39·4 tons during the pre-war quinquennium to 36·6 tons during the war quinquennium and 35·0 tons during the quinquennial period 1919-23. There was apparently a very heavy fall during the period now under review, when the output was only 26·6 tons per person employed. The decrease during the three earlier periods was due to the depletion of the supplies of easily-won ore so that an increasing amount of dead work became necessary every year. The large decrease during the period 1924-29 is mainly due to the fact that under the revised Mines Act of 1924, all the small inefficiently worked quarries, which were previously excluded, are now included. The output of coal per person employed was nearly three times the above figure. The death rate was 0·37 per 1,000 persons employed, as compared with 1·16 in the case of coal: these figures are lower than for the period 1919-23, when the corresponding figures were 0·40 and 1·36 respectively. At the same time the number of deaths per million

[1] The lower rates refer to cultivators in Madras who combine mining with agriculture.

tons won has increased in the case of manganese from 6 in 1914-18, to 11·3 in 1919-23, and 13·8 in 1924-28, and in the case of coal from 10·7 to 13·9 and 10·1.

TABLE 62.—*Daily number of workers employed at the Manganese Mines from 1924 to 1928.*

Year.	Bihar and Orissa	Bombay.	Central India.	Central Provinces.	Madras.	Mysore.	TOTAL.
1924 . .	2,183	3,447	354	20,787	2,727	927	**30,425**
1925 . .	2,131	3,580	315	21,644	2,443	1,005	**31,118**
1926 . .	2,183	3,923	502	25,296	2,641	1,036	**35,581**
1927 . .	2,281	5,750	714	25,853	3,576	774	**38,978**
1928 . .	2,175	1,247	578	23,496	3,398	516	**34,710**
Average .	*2,251*	*4,189*	*499*	*23,415*	*2,957*	*851*	*31,162*

TABLE 63.—*Labour statistics for Manganese mines under the revised Mines Act, 1923.*

Year.	Average number of persons employed daily.	Production.	Output per person.	Number of deaths.
		Tons.	Tons.	
1924	25,088	668,331	26·6	13
1925	26,189	710,347	27·1	8
1926	30,094	857,099	28·5	10
1927	32,927	878,521	26·7	15
1928	29,595	716,626	24·2	7
TOTAL .	**143,893**	**3,830,924**	..	**53**
Average .	*28,779*	*766,185*	*26·6*	*10·6*

Cost of mining and transport.

The chief items in the cost of placing manganese-ore on the markets in Europe and America are the following:—

(1) Cost of mining (labour, tools, plant, establishment).
(2) Cost of transport to the railway.
(3) Cost of transport to the port of shipment.
(4) Cost of handling at the port of shipment.
(5) Cost of shipping to Europe or America.
(6) Destination charges.

Each of these six items—the first five of which vary according to the situation of the deposit—has been considered in detail in *Memoirs, Geol. Sur. Ind.*, XXXVII, Chapter XXIII, to which the reader is referred. In an earlier review an abstract was given showing the average cost of delivering *c.i.f.* at English and Continental ports ore derived from several of the producing areas. These figures were in the main based on information collected prior to 1910, and with the general rise in prices due to the war have ceased to be applicable. Revised figures for all the areas concerned have not been obtained, but it will be sufficient to give as an example the following revised figures for the Central Provinces, the most important producing province.

—	*Viâ* Bombay.			*Viâ* Calcutta.		
	Limits.		Average.	Limits.		Average.
	Rs. A. P.	Rs. A. P.	Rs. A.P.	Rs. A. P.	Rs. A. P.	Rs. A. P.
Cost of mining (labour, tools, plant and administration).	5 0 0	13 2 0	6 8 0	..	..	6 8 0
Transport to rail-head . .	0 3 0	6 0 0	1 8 0	..	..	1 8 0
Railway freight . . .	11 15 0	14 1 0	12 8 0	11 10 4	14 0 0	12 4 0
Handling at port . .	2 10 6	4 2 6	2 14 0	2 0 0	3 2 0	2 4 0
Agents' commission and administration.	0 2 9	1 2 0	0 12 0	0 2 9	1 2 0	0 12 0
			24 2 0			23 4 0

These figures are applicable to the period 1924 to 1928 and on comparing them with the figures given in the memoir referred to above and in the previous review, it will be seen that the average cost of delivering ore from the Central Provinces *f.o.b.* Bombay increased from about Rs. 14 per ton in the pre-war quinquennial period and about Rs. 17 during the war quinquennium to about Rs. 24 (£1=Rs. 15) during the post-war quinquennium and to about Rs. 24 (£1=Rs. 13·3) during the quinquennium under review. These increases are due to increases under every item in the total, and in effect, taking an exchange value for the rupee of 1*s.* 6*d.*, it will be seen that the cost of delivering manganese-ore *f.o.b.* Bombay has increased by about 80 per cent., as compared with pre-war costs with exchange at 1*s.* 4*d.* A comparison of the figures given in Table 55 with the average price of first-grade manganese-ore per

unit during the pre-war quinquennium *f.o.b.* Indian ports (6·18*d.*) will show that the increased market price of manganese-ore has met adequately the increased cost of production. A fall in *c.i.f.* prices from 17·0*d.*, the average figure for 1928, to 13 pence would, however, extinguish the profit based on cost of production of Rs. 24 per ton *f.o.b.*

Royalties. In British India the royalty leviable on the base metals is—

'2½ per cent. on the sale value at the pit's mouth, or on the surface, of the dressed ore or metal, convertible at the option of the Local Government to an equivalent charge per ton to be fixed annually for a term.'

On account of the inconvenience and labour involved in assessing rates of royalty separately for each manganese-ore deposit and producer, it has for some years been customary in each area to assume average figures for the composition of the ore and for the costs of mining, transport, etc., and to apply them without distinction to all cases. The first sliding scale drawn up on these assumptions was framed by the Central Provinces administration and was based on *c.i.f.* values at United Kingdom ports: during the war period the high ocean freights upset the schedule and it was replaced by the following sliding scale based on *f.o.b.* values Bombay :—

TABLE 64.—*Royalties, in annas per ton, leviable on Manganese-ore extracted in the Central Provinces and Bombay.*

F.o.b. price per unit of first-grade ore.	Royalty leviable per ton of ore.
Pence.	*Annas.*
5½	½
6	1⅕
6½	1⅘
7	2⅖
7½	3
8	3⅗
8½	4⅕
9	4⅘
9½	5⅖
10	6

The wide fluctuations in the rupee-sterling exchange during the post-war period rendered this schedule also inapplicable: it would have been easy to rectify this difficulty by basing royalties on the *f.o.b.* price stated in annas instead of pence, but on account of the possibility of variation of other factors, the Local Government decided in 1921, to abandon sliding scales altogether and to revert

to the system of assessing royalty at 2½ per cent. on the sale value of the ore at the pit's mouth. This necessitates detailed returns by each producer based on the actual facts of each year and forms suitable for the purpose have been drawn up. The royalties charged according to this method are shown in Table 65. The actual rates of

TABLE 65.—*Average royalties in annas per ton charged on Manganese-ore in the Central Provinces during each half year for the years 1924 to 1928 on concessions granted after the 6th June 1921.*

	January to June.	July to December.
	Annas.	*Annas.*
1924	6·1	7·0
1925	7·1	6·3
1926	6·9	5·7
1927	5·7	6·1
1928	5·5	5·1

royalty charged according to the sliding scale during the quinquennium in the Central Provinces are shown in Table 66. Bombay has adopted the same method of assessment.

TABLE 66.—*Royalties actually levied in the Central Provinces during the years 1924 to 1928.*

Year.	ROYALTIES LEVIED.		Average f.o.b. price for year.
	January to June.	July to December.	
	Annas.	*Annas.*	*Pence.*
1924	12·2	11·2	16·9
1925	11·2	12·2	16·0
1926	10·2	10·2	12·9
1927	9·6	9·0	13·4
1928	7·8	6·0	12·8

In Bihar and Orissa royalty is levied at 2½ per cent. on pit's mouth value, which has been taken as equivalent to 6 annas a ton during the last few years.

In the Native States a fixed royalty irrespective of price is usually arranged when a prospecting license or mining lease is granted. The rates prevailing in certain States are as follows :—

TABLE 67.—*Royalty, in annas per ton, levied in certain Native States and Zamindari lands.*

State.	*Royalty.*
Jhabua State, Central India . . .	4 annas.
Mysore State	From 1st April 1928, 10 annas per ton on all grades of ore subject to revision after 2 years (*a*).
Sandur State, Madras	6 annas.
The Vizianagram Samasthanum, Madras .	4 „

(*a*) From 1920, to October, 1924, the royalty was Re. 1-4 per ton for ores containing more than 44 per cent. of manganese, and otherwise annas 12 per ton. From October, 1924, licensees were, in addition, required to pay to Government not less than 25 per cent. of the net profits. In March, 1926, the royalty on low grade ore was raised to annas 6 per ton.

Valuation of manganese-ore.

From Table 54 and the diagram (fig. 12) on page 181, it will be seen that the price per unit of manganese, and consequently the price per ton of manganese-ore obtained on its delivery *c.i.f.* at the port of destination, is subject to great variations. Up till November, 1909, (*Mining Journal*) the following classification was in use :—

1st grade	50 per cent. Mn. and upwards.
2nd „	47—50 per cent. Mn.
3rd „	40—47 per cent. Mn.

But from December, 1909, the following schedule was employed :—

1st grade	50 per cent. Mn.
2nd „	48—50 per cent. Mn.
3rd „	45—48 per cent. Mn.

and during the war quotations have been given for first-grade ore only. Since the war, also, quotations have been practically confined to first-grade ore; but of late quotations for second-grade ore

have appeared at intervals, and have been usually about one or two pence below first-grade prices. The lower limit for first-grade ore has fallen to 48 per cent. Mn.

As an example of the way in which the schedule of prices was applied we can take the case of a 50 per cent. ore from the Central Provinces in December, 1914. The average price at this time was 11 pence per unit. The price then paid per ton for this ore would be 50×11 pence=£2-5-10.

The prices given in Table 54, apply to ore delivered in the United Kingdom; and for this scale to be applicable it was formerly necessary that the ore should not contain more than 10 per cent. of silica and 0·10 per cent. of phosphorus.

Before the War, a schedule of prices was fixed periodically by the Carnegie Steel Company and one such schedule is quoted in a previous Quinquennial Review. The great rise in prices during the war period led to the announcement in 1918, by the War Industries Board of a revised schedule fixing the price per unit of manganese for each 1 per cent. rising from 35 per cent. upwards. This schedule also no longer applies, and manganese-ores are now quoted *c.i.f.* docks at prices per unit roughly equivalent to the sterling price per unit *c.i.f.* U. K. ports The import duty is additional and amounts to 1 cent. per pound of metallic manganese in ores and concentrates containing over 30 per cent. of manganese.

Valuation for chemical purposes.

The prices noticed above are those relating to manganese-ores intended for use in the iron and steel industry. For ores suited for use in the chemical industries as oxidising agents much higher prices are often obtained. For chemical purposes it is not the percentage of manganese that is of importance, but the percentage of oxygen liberated on treating the ore with acid, *i.e.*, the *available oxygen.* This is usually expressed in terms of the percentage of manganese peroxide, MnO_2. Not only does the percentage of MnO_2 affect the price, but also the ease with which the oxygen is liberated. Further, impurities that are soluble in acid, and so cause an unnecessary consumption of it, are deleterious. The best minerals for chemical purposes are pyrolusite, psilomelane, and hollandite. For the glass industry the ore must be as free as possible from iron. The only Indian pyrolusite yet found sufficiently pure for the glass industry is that of Pali in the Nagpur district. A picked specimen of this giving 95·57 per cent. MnO_2 showed only 0·06 per cent. Fe_2O_3.

It is customary to divide the ores of iron and manganese into iron-ores, manganiferous iron-ores, and manganese-ores. The least percentage of manganese in an iron-ore that is usually paid for is said to be 5 per cent. and with less than 5 per cent. of manganese it hardly seems necessary to prefix the adjective 'manganiferous'. The dividing line between manganiferous iron-ores and manganese-ores was formerly taken at 44 per cent. manganese (=70 per cent. MnO_2). Later, ores with as little as 40 per cent. manganese have been termed manganese-ores, and those below this limit manganiferous iron-ores.[1] According to this method one often sees an ore referred to as manganiferous iron-ore that contains much more manganese than iron. Such a difficulty can easily be avoided by creating a class for *ferruginous manganese-ores*. Accordingly, in *Memoirs, Geol. Surv. Ind.*, XXXVII, page 500 (1909), the following classification was proposed. It is applicable to all ores containing over 50 per cent. of Mn+Fe. The term *Ferruginous manganese-ores* is now coming into general use.

Nomenclature of manganese-ores and manganiferous iron-ores.

—	Mn. per cent.	Fe. per cent.
Manganese-ores	40—63	0—10
Ferruginous manganese-ores . .	25—50	10—30
Manganiferous iron-ores . . .	5—30	30—65
Iron-ores	0—5	45—70

On pages 501 to 509 of the work cited above a series of tables of analyses of Indian ores will be found. A good idea of the quality of the ores obtained in different parts of India can be gleaned from the range and mean values of these analyses as summarised in the tables 71 and 72 of the review for the period 1914-18. The second of

Analyses of manganese-ores.

[1] In the United States in 1918, the limiting percentage was lowered to 35, and the following classification is now used :—

Manganese-ores	35 per cent. and over.
Ferruginous manganese-ores	10 to 35 per cent.
Manganiferous iron-ores	5 to 10 per cent.

The middle sub-division includes ores that would be better termed manganiferous iron-ores.

these only is now repeated (Table 68), but in addition another (No. 69) is added representing the composition of the manganese-ores worked in India during the quinquennial period under review and based on figures for which I am indebted to the various mining companies. Certain differences between the figures in these two tables merit comment. In the case of the Panch Mahals, the figures given in Table 68 relate to outcrop samples taken before the deposits were opened up and without any selection, such as would naturally take place when the ores were worked; the average quality of ore as exported is of much higher grade. The ores from the Central Provinces worked during the present period show a slight decrease in manganese contents, a slight increase in silica contents, and a slight increase of phosphorus contents, compared with the analyses summarised in Table 68, which relate chiefly to samples taken by myself in 1903-04. The ores from Sandur State as exported show roughly the same total manganese and iron contents, as in the earlier figures, but the iron contents are markedly higher at the expense of the manganese contents.

Analyses of cargoes of Indian and foreign ores landed at Middlesborough.

In order to show the value of the Indian ores relative to those of certain foreign countries two tables (73 and 74) were given in the review for 1914-18 showing the limits and averages, respectively, of a large number of cargoes of manganese-ores and manganiferous iron-ores landed during the years 1897-1906 at Middlesborough. In the present review only the table of average values is repeated. These figures represent not only Indian manganese-ores, but also the manganese-ores of the Caucasus, Brazil and Chile, and the manganiferous iron-ores of Greece and Spain (*viâ* Carthagena). From these figures it will be seen that the Indian ores contain less moisture than those of the other countries. Some of the latter contain such large quantities of moisture—Caucasus, 8·67 per cent.; Brazil, 11·35 per cent.; and Spain, 8·44 per cent.—that it is necessary to reduce the analyses to their condition when dried at 100° C. before any fair comparison can be made. This has been done by assuming that the constituents of the ores not given in the 'as received' columns would if determined make the analyses add up exactly to 100. From the figures representing the dried ores it will be seen that the Indian ores stand first as regards manganese contents, with Brazil a close second; as regards silica, Brazil stands first, with India second; as regards phosphorus, however, India stands last but one, the only ores containing more phosphorus being those of Russia;

TABLE 68.—*Mean of analyses of Manganese-ores and Manganiferous Iron-ores from the different districts and provinces of India.*

PROVINCE.	BIHAR AND ORISSA.				BOMBAY.				CENTRAL INDIA.	CENTRAL PROVINCES.	
DISTRICT.	GANGPUR.		SINGHBHUM.		BELGAUM.		PANCH MAHALS.	SATARA.	JHABUA.	BALAGHAT.	BHANDARA.
Class of ore.	Higher grade.	Lower grade.	Manganese-ore.	Manganiferous iron-ore.	Ferruginous manganese-ore.	Manganiferous iron-ore.	Manganese-ore.	Manganese-ore.	Manganese-ore.	Manganese-ore.	Manganese-ore.
Number of analyses.	Half the limits.	Half the limits.	3	3	10	2	4	4	5	13	13
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Manganese	49·5	45	47·66	11·84	44·77	10·53	41·66	40·79	46·94	51·88	51·94
Iron	7	7·5	2·90	34·93	10·33	49·55	4·07	6·94	8·44	7·40	7·27
Silica	6	8	4·63	16·46	1·40	2·27	19·11	3·75	8·14	3·74	4·59
Phosphorus	0·18	0·13	0·34	0·74	0·035	0·023	0·20	0·07	0·20	0·11	0·14
Moisture	..	..	0·63	1·17	..	..	0·35	1·99	0·43	0·37	0·44
Manganese + iron	56·5	52·5	50·56	46·77	55·10	60·08	45·75	47·73	55·88	59·28	59·21

TABLE 68 (*contd*).—*Mean of analyses of Manganese-ores and Manganiferous Iron-ores from the different districts and provinces of India.*

PROVINCE.	CENTRAL PROVINCES—*contd.*					MADRAS.				MYSORE.		
										SHIMOGA.		
DISTRICT.	CHHINDWARA.	NAGPUR.	JUBBULPORE.			SANDUR	VIZAGAPATAM.			New Mysore Manganese Company.		Shimoga Manganese Company.
Class of ore.	Manganese-ore.	Manganese-ore.	Manganese-ore.	Manganiferous iron-ore.	Iron-ore.	Ferruginous manganese-ore.	Ferruginous manganese-ore.	Supplied by Vizianagram Mining Company.		Ferruginous manganese-ore.		Manganese ore.
								Manganese-ore.	Ferruginous manganese-ore.	Higher grade.	Lower grade.	
Number of analyses.	8	30	3	7	4	6	12	8	7	3	Half the limits.	9
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Manganese	52·72	51·53	45·56	20·26	0·96	47·75	42·96	44·34	46·75	46·75	37	49·10
Iron	7·08	6·24([illegible])	4·79	28·78	50·50	11·45	11·22	9·08	15·20	10·06	15	7·74
Silica	7·16	7·25	2·68	12·99	10·76	0·61	4·29	4·15	5·72([illegible])	1·77	4	2·62
Phosphorus	0·14	0·11	0·215	0·25	0·32	0·030	0·27	0·32	0·385	0·031	0·035	06·85
Moisture	0·38	0·49 ([illegible])	0·56	..	0·336	..	0·90	..	..	0·95	1	..
Manganese + iron	59·80	57·77	50·35	49·04	51·4	59·20	54·18	53·42	51·95	56·81	52	6·84

TABLE 69.—*Composition of Indian Manganese-ores as exported.*

PROVINCE.	BIHAR AND ORISSA.			BOMBAY.				
PRODUCER.	NEW GANGPUR MINING SYNDICATE.	BIRD & CO.		SHIVRAJPUR SYNDICATE (*a*).				
District or State.	*Gangpur* (*a*)	*Kheonjhar* (*b*).		*Chhota Udepur* (*d*).	*Panch Mahals.* Shivrajpur.			*Bamankua* (*d*)
Class of ore.	2nd grade.	1st grade.	2nd grade.	1st grade.	1st grade.	2nd grade.	Low grade.	1st grade.
Tonnage represented . . .	47,659	28,820	1,11,160	34,044	98,182	78,593	45,016	36,796
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Manganese	46·5	48·1 —49·9	39·74 —42·29	48·3	50·8	46·8	43·7	50·0
Iron	7·0	12·01 — 8·92	19·44 —18·57	4·14	4·81	3·81	8·77	3·81
Silica	6·5	1·78 — 2·8	3·07 — 5·89	4·40	4·60	10·07	15·27	6·36
Phosphorus	0·174	0·071— 0·114	0·062— 0·121	0·150	0·218	0·210	0·190	0·231
Manganese + Iron . . .	53·5	57·96 —60·3	55·72 —59·18	52·44	55·61	50·61	47·47	53·81

(*a*) Analysis of ore produced. (*b*) Analysis of ore despatched. (*d*) 2nd grade and lower grade ores also produced.

TABLE 69 (*contd*).—*Composition of Indian Manganese-ores as exported.*

PROVINCE.	CENTRAL INDIA.	CENTRAL PROVINCES.						
PRODUCER.	SHIVRAJPUR SYNDICATE.	CARNEGIE STEEL COMPANY.	CENTRAL INDIA MINING COMPANY.			CENTRAL PROVINCES MANGANESE ORE COMPANY (*a*).		
District or State.	*Jhabua* (*a*).	*Balaghat* (*a*).	*Balaghat, Bhandara, and Nagpur* (*a*).			*Balaghat, Bhandara, and Nagpur.*		*Bhandara* (Dongri Buzurg).
Class of ore.	Low grade.	1st grade.	1st grade.	2nd grade.	Low grade.	1st grade.	2nd grade.	Peroxide.
Tonnage represented . .	27,782	33,925	168,082	81,059	17,903	1,394,598	311,786	13,499
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Manganese . . .	43·7	48·83 —51·96	48·48 —48·76	45·21 —45·55	42·30 —42·50	47·31 —54·75	43·07 —49·28	54·43 —55·11
Iron	9·70	3·3 — 6·6	..	..	..	4·63 —11·70	5·94 —13·15	4·21 — 4·77
Silica	12·04	2·8 — 7·29	6·01 — 9·94	6·40 —11·50	13·83 —14·50	3·20 —12·18	2·34 —13·42	2·32 — 2·74
Phosphorus . . .	0·218	0·036— 0·912	0·152— 0·161	0·150— 0·250	0·235— 0·260	0·055— 0·196	0·056— 0·521	0·286— 0·371
Manganese + Iron . .	53·40	55·26 —57·18	..	..	..	53·86 —60·66	53·57 —59·09	58·86 —59·37

(*a*) Analysis of ore produced.

TABLE 69 (*concld*).—*Composition of Indian Manganese-ores as exported.*

PROVINCE.	CENTRAL PROVINCES—*contd.*			MADRAS.			MYSORE.
PRODUCER.	INDIAN MANGANESE COMPANY (*c*).			GENERAL SANDUR MINING COMPANY.	VIZIANAGRAM MINING COMPANY.		UNITED STEEL COMPANIES.
District or State.	*Chhindwara.*		*Nagpur.*	*Sandur* (*c*).	*Vizagapatam.*		*Shimoga.*
Class of ore.	1st grade.	2nd grade.	1st grade.	Ferruginous manganese-ore.	Ferruginous manganese-ore.		Ferruginous manganese-ore.
Tonnage represented . .	156,720	29,226	112,953	556,650	Higher grade.	Lower grade.	..
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Manganese . . .	51·35 —52·39	43·68 —44·70	48·08 —49·58	38—39	42·8 —48·6	33·1 —37·6	36—38
Iron	4·76 — 5·13	6·18 — 7·42	6·36 — 7·77	19—18	(*d*)	(*d*)	10·6—11·6
Silica	8·43 — 9·02	10·40 —12·88	8·19 — 8·82	2	(*d*)	(*d*)	9·4—10·6
Phosphorus . . .	0·135— 0·163	0·193— 0·252	0·182— 0·227	0·04	(*d*)	(*d*)	0·023—0·026
Manganese + Iron . .	56·34 —57·21	50·88 —51·15	54·95 —56·64	57	..	..	.

(*c*) Analysis of ore shipped. Tonnages are of ore produced.
(*d*) Not available.

the Indian ores contain much less iron than the manganiferous iron-ores of other countries; but of the true manganese-ores they contain the highest amounts of iron, in spite of the fact that they also contain the highest amounts of manganese. The high iron contents of the Indian ores may be regarded as a point in their favour, or otherwise, according to the use to which the ores are to be applied. It is true that the high iron contents make it more difficult to manufacture the very highest grades of ferro-manganese from the Indian ores; but, on the other hand, if the very highest grades are not required, then the iron is of considerable value. Both manganese and iron are of use in this case, and the buyer obtains the following totals of Mn+Fe when he buys the ores of the different countries :—

	Mn+Fe. Per cent.
India	**57·17**
Brazil	**54·09**
Russia	**50·41**
Chile	**48·40**
Greece	**47·99**
Spain	**44·27**

With the figures in Table 70 may be compared the analyses of the average ore from the Gold coast* :—

	Per cent.
Manganese	**50—53**
Iron	**2—4**
Silica	**3—7**
Phosphorus	**0·1—0·12**

As regards phosphorus, the figures for the Indian ores are rather misleading; for an examination of the analyses from which these figures have been taken shows that the ores consist of two different varieties. The majority of analyses are typical of the ores of the Central Provinces, whilst four of them probably represent ores from the Vizagapatam district. I have accordingly separated them into two groups, of which the mean values are given in Table 71. From these figures it will be seen that the Central Provinces ores average 0·096 per cent. and the Vizagapatam ores 0·291 per cent. in phosphorus. With the gradual rise that is taking place in the phosphorus contents of the ores won in the Central Provinces, however, it is probable that the average figure given in Table 70 now corresponds closely with that for the Central Provinces.

* **Sir A. E. Kitson, Bull. No. 1, Gold coast Geol. Surv., p. 15, (1925).**

TABLE 70.—*Means of analyses of cargoes of Manganese-ores and Manganiferous Iron-ores landed at Middlesborough during the ten years 1897 to 1906.*

COUNTRY.	INDIA.		(CAUCASUS).		BRAZIL.		CHILE.		GREECE.			SPAIN (*viâ* CARTHAGENA).	
Class of ore	Manganese-ore.		Manganese-ore.		Manganese-ore.		Manganese-ore.		Manganiferous, iron-ores. *Raw.*		Manganiferous, iron-ores. *Calcined.*	Manganiferous iron-ores.	
Number of cargoes	26		77		25		9		54		18	24	
Period	1900—1906		1898—1906		1898—1906		1898—1903		1897—1906		1897—1903	1897—1905	
Method of reporting analysis.	As received.	Dried at 100°C.	As received.	Dried at 100°C.	As received.	Dried at 100°C.	As received.	Dried at 100°C.	As received.	Dried at 100°C.	Dried at 100°C.	As received.	Dried at 100°C.
Manganese	50·49	50·86	45·28	49·58	44·60	50·314	47·51	47·99	16·15	16·96	43·01	19·35	21·13
Iron	6·26	6·31	0·76	0·83	3·35	3·78	0·41	0·41	29·54	31·03	41·32	21·19	23·14
Silica	5·67	5·71	9·29	10·17	1·81	2·04	7·26	7·33	7·37	7·33	7·33	11·18	12·21
Phosphorus	0·126	0·127	0·147	0·161	0·040	0·052	0·015	0·011	0·022	0·023	0·023	0·013	0·014
Moisture	0·72	..	8·67	..	11·35	..	1·01	..	4·59	..	..	8·44	..
Alumina, siliceous matter, etc. .	0·75	6·80	11·66	12·77	2·73	3·08	12·52	12·65	8·04	8·44	8·35	12 63	13·79

TABLE 71.—*Mean of analyses of Indian ores in Table 70 arranged according to probable source.*

Source of ore.	Central Provinces and possibly Jhabua and Panch Mahals.	Vizagapatam.
Number of cargoes.	22	4
Manganese	51·31	45·95
Iron	5·53	10·29
Silica	6·13	3·10
Phosphorus	0·096	0·291
Moisture	0·71	0·76

The valuation of the Indian manganese-ore production is a question of some interest. There are of course several ways of stating the value. Manganese-ore possesses one value per ton as stacked at the pit's mouth, another as delivered *f.o.r.* at the rail-head, a third as delivered *f.o.b.* on board the ship at the port of shipment, a fourth as delivered *c.i.f.* at the port of destination, and a fifth after it has been converted into ferro-manganese. For example, with the price at 17 pence per unit, the average value of 50 per cent. Central Provinces ore, with 1928 data for freight charges, etc., exported *viâ* Bombay may be taken as :—

Value of the Indian manganese-ore production.

Rs.	AS.	
14	12	at the pit's mouth.
16	4	*f.o.r.*
35	10	*f.o.b.*
47	4	*c.i.f.*

The question of values is discussed at length in *Memoirs, Geol. Surv. Ind.*, Vol. XXXVII, Chapter XXV, and it is there shown that to obtain a true idea of the value of the industry to India the export or *f.o.b.* values must be considered. But it is also pointed out that the true value of the ore in the world's markets is the *c.i.f.* value. The export values formerly given were obviously much too low; they were based on figures supplied by the mine operators, and represented, apparently, the cost of winning the ore and placing it on

board a ship at the port, and not the true value of the ore, which is the *c.i.f.* value *minus* charges incurred from the port of shipment to the port of destination. In the work already cited the export values have been re-calculated from the beginning of the industry. First the *c.i.f.* values per ton have been calculated separately for each area, on the basis of the average market price per unit of manganese-ore during the year, and an assumed average composition of the ores. From these *c.i.f.* values the *f.o.b.* values are obtained by deducting freights *plus* destination charges from the *c.i.f.* value per ton. The *f.o.b.* value per ton is then multiplied by the actual production for the year. The figures thus calculated for the years 1924 to 1928 are given in Table 72.

TABLE 72.—*Export value f.o.b. at Indian ports of the Manganese-ore produced in India during the years 1924 to 1928.*

Year.	Bihar and Orissa.	Bombay.	Central India.	Central Provinces.	Madras.	Mysore.	Total.	Value per Ton.
	£	£	£	£	£	£	£	£
1924 .	109,572	188,420	6,016	2,063,841	167,524	84,201	**2,619,574**	3·262
1925 .	94,824	188,959	8,175	1,994,087	167,006	59,236	**2,512,287**	2·993
1926 .	75,994	179,901	15,905	1,989,067	160,665	41,959	**2,463,491**	2·427
1927 .	142,231	247,602	21,414	1,974,299	269,288	48,234	**2,703,068**	2·393
1928 .	202,657	181,283	7,447	1,504,928	254,705	47,875	**2,198,895**	2·247
TOTAL .	**625,278**	**986,165**	**58,957**	**9,526,222**	**1,019,188**	**281,505**	**12,497,315**	..
Average.	*125,056*	*197,233*	*11,791*	*1,905,244*	*203,838*	*56,301*	*2,499,463*	*2·664*

There is, however, in many years a considerable difference between the amounts of ore won and the amounts exported; during the preceding quinquennium, in two years, namely 1919 and 1921, the amounts of ore won exceeded greatly the amounts of ore exported, whereas in the remaining three years the reverse relation held, the disparity being greatest in 1922. In the present quinquennium the amounts of ore won have in each year exceeded the amounts exported. The totals obtained as above differ, therefore, considerably from the total values actually obtained by the mining community. As figures for the amounts of ore exported are not obtainable in detail province by province the totals may

be adjusted for these years by valuing the exports for the calendar years ending 31st December at the average value per ton derived from the total production. Treated in this way the total values for 1924 to 1928 become—

	£
1924	2,500,157
1925	2,211,381
1926	1,489,052
1927	2,019,264
1928	1,874,322

and these figures have been used in the table of total values (Table 1, page 6).

Comparing the export values of the manganese-ore production with the values for the other chief Indian mineral products given in Table 1 it will be seen that manganese now occupies the third place.

Manufacture of ferro-manganese in India.

In earlier reviews reference was made to the potential loss that India suffers through exporting her manganese-ore in the raw condition, instead of converting at least a portion of it into ferro-manganese in the country. It was satisfactory, therefore, to be able to record in the previous review that during the war quinquennium the manufacture of ferro-manganese had been inaugurated in India. On account of the great increase in the price due to the war, one of the blast furnaces at Sakchi was diverted to the manufacture of ferro-manganese in October, 1915, the average output from one furnace being about 80 tons a day. In 1917, the manufacture of ferro-manganese at Sakchi was discontinued on account of the necessity of keeping both blast furnaces on the production of pig-iron required for the manufacture of steel. The average composition of the ferro-manganese produced was :—

	Per cent.
Manganese	70
Phosphorus	0·55—0·66
Silicon	2—3

From November, 1917 one of the smaller blast furnaces of the Bengal Iron Company at Kulti was engaged in the production of ferro-manganese with a guaranteed minimum of 74 per cent. manganese and maximum of 0·55 per cent. phosphorus. The average monthly

output was given as 1,150 tons, and the balance left over after satisfying the requirements of Sakchi, was exported, the total exports (to France, United States, Italy, and Natal) up to the end of August, 1918, being 7,555 tons. With the cessation of the war the production of ferro-manganese was discontinued at Kulti and resumed at Sakchi. The production of ferro-manganese in India during the quinquennium is shown in Table 73.

TABLE 73.—*Production of Ferro-Manganese in India during the years 1924 to 1928.*

Year.	Quantity.
	Tons.
1924	8,951
1925	6,527
1926	10,503
1927	5,092
1928	12,265
TOTAL .	43,338
1919-23	16,956

The ore used at Sakchi was in part railed from the company's mines in the Central Provinces, the average composition of the ore railed during 1917 being as follows:—

	Per cent.
Manganese	50·41
Iron	6·38
Silica	4·36
Phosphorus	0·041

That smelted at Kulti was purchased from the Central Provinces Prospecting Syndicate, but figures of composition have not been obtained.

The composition of the coke used at the two works was as follows:—

——	Sakchi.	Kulti.
	Per cent.	Per cent.
Moisture	6·54	2·2
Volatile matter	1·63	7
Fixed carbon	72·28	..
Ash	19·53	20
Sulphur	0·64	..
Phosphorus in ash	0·935	..

As will be seen from the figures given above the phosphorus contents of the alloy produced at Sakchi and Kulti were considerably higher than the figure 0·30 per cent. representing the upper limit of phosphorus acceptable abroad in normal times. With a careful selection of Indian ores (*e.g.*, of the composition of that already smelted at Sakchi, or ore from Balaghat running 0·07 per cent. phosphorus) and the use of Giridih coke running only 0·022 per cent. phosphorus, ferro-manganese could be produced with phosphorus within the acceptable figure. But considering that the amount of Giridih coke is limited, that Indian cokes are normally high in phosphorus, and that the percentage of phosphorus in the high-grade manganese-ores of the Central Provinces is slowly increasing with depth from the surface, it is evident that India can never be a large producer of low-phosphorus ferro-manganese by blast-furnace methods. The possibilities of the electric production of such low-phosphorus alloy deserve, therefore, careful consideration.

TABLE 74.—*Statistics of Manganese-ore received and consumed at the iron and steel works of India.*

(Statute Tons).

	Tata Iron and Steel Co.			Bengal Iron Co.			Indian Iron and Steel Co.		
	Ore received.	Ore consumed.	Ore sold.	Ore received.	Ore consumed.	Ore sold.	Ore received.	Ore consumed.	Ore sold.
1913 (up to and including)	9,901	8,561	..	615	..	..	..	..	..
1914	6,792	7,804	..	1,122	..	..	..	..	..
1915	21,066	12,485	60	1,254	..	..	..	..	..
1916	5,646	8,137	1	1,389	..	..	..	..	..
1917	*nil*	6,356	..	10,326	..	..	..	..	..
1918	31,839	5,748	..	31,746	..	..	..	..	..
1919	81,737	8,637	..	4,748	..	..	..	..	..
1920	19,849	5,414	..	4,580	..	..	..	..	..
1921	*nil*	15,885	..	1,138	..	..	..	..	..
1922	20,799	8,864	..	5,070	..	..	307	81	..
1923	*nil*	16,175	36,061	3,558	..	..	2,229	2,144	..
1924	16,863	25,660	29,192	4,420	..	..	6,050	5,260	..
1925	21,044	20,943	10,268	2,264	..	..	14,934	11,636	..
1926	25,039	29,581	3,029	..	..	..	13,226	9,985	..
1927	25,027	19,733	..	5,043	..	..	18,915	14,869	..
1928	25,129	26,765	..	25,505	..	..	27,919	19,852	..
TOTAL	317,931	226,748	78,611	102,778	98,843	..	83,580	63,827	..

	Tons.
Total ore received	504,289
Total ore consumed	389,418
Total ore sold	78,611
Total ore stocks December 31st, 1928	36,260

The fact that ferro-manganese is now being made in India renders it important to secure statistics of the amounts of manganese-ore railed to Tatanagar and Kulti and consumed in India, in order to enable one to deduce what portion of the difference between the figures of production of manganese-ore in India and exports thereof represents accumulated stocks. These data are collected in Table 74, from which it will be seen that the total quantity of ore railed to Tatanagar, Kulti, and Burnpur, up to 31st December, 1928, is 504,289 tons, of which 389,418 tons have been consumed, and 78,611 tons resold, leaving stocks of ore at the works amounting to 36,260 tons. It must be mentioned that manganese-ore is used not only in the manufacture of ferro-manganese, but is also added to the blast furnace charge in the manufacture of pig-iron, and in the open-hearth furnaces. Thus the Tata Iron and Steel Co. during the past quinquennium consumed 29,772 tons of manganese-ore in the manufacture of pig-iron, 20,186 tons in the manufacture of ferro-manganese, and 4,717 tons in the open-hearth steel furnaces.

Other economic considerations.

The thoroughness with which India was prospected for deposits of manganese-ores during the first eight years or so of this century is shown by the fact that, during the quinquennial period, 1909-13, no fresh fields of importance were discovered, nor were any new deposits of importance located in areas already under exploitation; whilst during the succeeding period one fresh deposit only was opened up, namely Pani in Chhota Udepur, Bombay Presidency, the initial production of which dates from 1914, and which has yielded 172,681 tons of ore up to the end of the present quinquenium. During the period of the previous review, manganese-ores were discovered in the iron-ore tracts of Keonjhar State in Orissa, and there was a small initial production in 1923, increasing to 191,469 tons during the present quinquennium. Work was also commenced (1926) on the lateritoid deposits of North Kanara.

As before, work has been continued almost everywhere on open-cast lines, but underground mining is now in progress at Kandri in the Nagpur district, at the Balaghat mine,[1] and at Gariajhor in Gangpur.

With regard to the effects on output of the steadily increasing depth of the Indian manganese quarries, as would be expected.

[1] B. V. Mellon; *Trans. Min. and Geol. Inst. Ind.* XXIV, pp. 165-174, (1929).

deposits of superficial origin, such as those of Vizagapatam, are, with the passage of years, giving a markedly decreased yield. But deposits of the gonditic type (chiefly in the Central Provinces) show no evidence of deterioration in depth, except when structural factors intervene, and except, also, for the very slight decrease in manganese contents and slight rise in silica and phosphorus contents that characterise many of these deposits, which features may, as noted in a previous review, be regarded as evidence of a certain amount of surface modification of these ores, originally consolidated in depth. With the continuous output of ore still yielded by so many of the Central Provinces deposits the mining companies have not yet been impelled to test, by boring, the continuity of their deposits in depth.

In the review for 1914-18, the abandonment was recorded of an important deposit of the gonditic type, namely Kajlidongri in the Jhabua State. During the quinquennium now under review, work was resumed at this locality, but on a much smaller scale than previously.

The year 1919 saw the abandonment (except for surface boulder accumulations) of a second valuable gonditic deposit, namely Sitapar in the Chhindwara district. This deposit was worked from a large open quarry, until at about 100 feet from the surface the ore-body was truncated by felspathic intrusives. The circumstances render it possible that the remainder of the ore-body may lie concealed underground in one or more fragments. From the commencement of work in 1906, until the end of 1921, the Sitapar deposit yielded 70,600 tons of ore of exceptionally high grade, and in addition no less than three minerals new to science (see also page 226).

As several of the ores of manganese are distinctly magnetic, though usually only slightly so, it seems desirable to determine the possibilities of magnetometric surveying in locating the position of underground bodies of manganese-ore. The prospects of success in such application of these methods do not seem very bright; but this much has been ascertained, that a dipping-needle set up directly on a manganese-ore deposit is often strongly affected thereby.

Geological Relations of Indian Manganese-ores.

In view of the importance of the Indian manganese industry it is proposed to repeat below, with such slight alterations as are

necessary, the brief sketch of the distribution and mode of occurrence of the Indian deposits given in the previous review. The deposits of economic value can be divided into three main groups.—

(*A*) Deposits associated with rocks of Dharwar age—the manganiferous facies of which is known, when containing spessartite-garnet, as the *gondite* series. Found in—

Bihar and Orissa :—*Gangpur.*
Bombay :—Narukot, *Panch Mahals, Chhota Udepur.*
Central India :—*Jhabua.*
Central Provinces :—*Balaghat, Bhandara, Chhindwara, Nagpur* and Seoni.

(*B*) Deposits associated with a series of manganiferous intrusives known as the *kodurite* series. Found in—

Madras :—Ganjam, *Vizagapatam.*

(*C*) Deposits occurring as *lateritoid* replacement masses on the outcrops of Dharwar rocks. Found in—

Bihar and Orissa :—*Keonjhar, Singhbhum.*
Bombay :—Dharwar, *North Kanara,* Ratnagiri.
Central Provinces :—*Jubbulpore.*
Goa.
Madras :—*Bellary, Sandur.*
Mysore :—*Chitaldrug, Kadur, Shimoga, Tumkur.*

(Italics denote that ore has been worked for export.)

In addition to the occurrences noted above, ore has been worked in the low-level laterite of Goa and the high-level laterite of Belgaum (though this occurrence—Talevadi—might perhaps be more accurately classed with the lateritoid occurrences). Manganese-ores have also been found in many other districts in India, but none of these other occurrences has been shown to be of any value. Amongst them, the following may be mentioned :—

In Bijawar rocks :—Dhar, Gwalior, Indore, Hoshangabad.
In Vindhyan rocks :—Bhopal.
In Kamthi rocks :—Yeotmal.
In Lameta rocks :—Dhar, Indore, Nimar.
In lateritic soil on the Deccan Trap :—Satara.

Each of the three chief groups will now be considered in turn.

A.—The Gondite Group.

The gondite series [1] is composed of metamorphosed manganiferous sediments of Dharwar age, and is characterised by the presence of various manganiferous silicates, the most important of which are the manganese-garnet, spessartite, and the manganese-pyroxene, rhodonite. The garnet occurs commonly as a rock composed of spessartite and quartz, and this is the rock that has been called *gondite*, after the Gonds, one of the aboriginal races of the Central Provinces. Other common rocks are spessartite-rock, rhodonite-rock, and rhodonite-quartz-rock. The series is developed typically in the districts of Balaghat, Bhandara, Chhindwara, and Nagpur, in the Central Provinces,[2] but has also been found in several other areas, namely:—Narukot State in Bombay, Jhabua in Central India, Gangpur State in Bihar and Orissa, and probably in Banswara State in Rajputana. It exists also in the Seoni district, Central Provinces.[3]

The gondite series.

Forming an integral portion of the same masses of rock as the gonditic rocks, there are, at many places, bodies of manganese-ore, often of large size and first-rate quality, some of the manganese-ore deposits of the Central Provinces being the most valuable in India, and second to none found in other parts of the world.

The rocks of the gondite series are supposed to have been formed by the metamorphism of a series of sediments deposited during Dharwar times. These sediments were partly mechanical (sands and clays) and partly chemical (manganese oxides). When these sediments were metamorphosed, the sands and clays were converted into quartzites, mica-phyllites and mica-schists; the purest of the manganese-oxide sediments were compacted into crystalline manganese-ores; whilst mixtures of the mechanical sediments, sand or clay, with the chemical sediment, manganese oxide, were converted into rocks composed of manganese silicates—spessartite and rhodonite—any silica left over, after accounting for the formation of these minerals, appearing as quartz. [The effects of regional metamorphism have been in some

Origin.

[1] *Mem. Geol. Surv. Ind.*, XXXVII, pp. 306—365.

[2] The series of Archæan schists and marbles in which the gonditic horizon occurs in the Central Provinces has been named the Sausar series. Names have also been allotted to each stage, that adopted for the gonditic horizon being the Mansar stage. Whereas the latter term is a stratigraphical term, gondite is a petrographical term. See L. L. Fermor; *Rec. Geol. Surv. Ind.*, LIX, pp. 77—79, (1926).

[3] R. C. Burton; *Ibid.*, XLIV, p. 21, (1914).

cases complicated by contact effects with resultant hybridism due to later intrusives.[1]] The rocks thus formed constitute the *gondite series.* There is abundance of evidence to prove that the manganese-silicate-rocks of the gondite series have been subjected to extensive oxy-alteration, subsequent to their formation, but probably in Archæan times. As a result of this alteration large bodies of manganese-ore have been formed; no decisive evidence has yet been obtained indicating the relative proportions of the workable ores that are the result of the direct compression of the purer portions of the original manganese-oxide sediments[2] and of the ores that have been formed by the subsequent alteration of the rocks of the gondite series.

Nagpur-Balaghat area: mode of occurrence.

The ore-bodies thus formed occur as lenticular masses and bands intercalated in the quartzites, schists, and gneisses; and, as would be expected from the suggested mode of origin, the ore is frequently found to pass, both laterally and along the strike, into the partly altered or quite fresh members of the gondite series, the commonest rock being gondite itself. The ore-bodies are often well-bedded parallel to the strike of the enclosing rocks, and several of them are often disposed along the same line of strike, indicating that they have probably all been produced from the same bed of manganiferous sediment. A good example of such a line of deposits is one in the Nagpur district, stretching from Dumri Kalan in an easterly direction as far as Khandala, a total distance of 12 miles, this line including the valuable deposits of Beldongri, Lohdongri, Kacharwahi, and Waregaon. With the enclosing rocks the ore-bodies have often suffered repeated folding, upon which is often superposed a well-marked pitch, which frequently, as at Kandri and Thirori, determines the direction of mining operations.

Dimensions of ore-bodies.

The ore-bodies often attain great dimensions. The Balaghat deposit is $1\frac{3}{4}$ miles long; at Manegaon in the Nagpur district the ore-body is $1\frac{1}{2}$ miles long; whilst the band running through Jamrapani, Thirori, and Ponia, in the Balaghat district, is exposed more

[1] L. L. Fermor; *Rec. Geol. Surv. Ind.*, XLV, p. 104, (1915).

[2] The fact that some of the gonditic manganese-ores are of great antiquity (at least pre-pegmatite in age) was conclusively proved by the discovery of a detached fragment of ore in pegmatite cutting the Gowari Warhona manganese-ore deposit, Chhindwara district. See *Rec. Geol. Surv. Ind.*, XLI, pp. 1—11, (1911). Similar phenomena were later well displayed at Sitapar in the same district, and are still to be seen at intervals at Kachhi Dhana.

TABLE 75. –*Total production of Manganese-ore from deposits of gonditic type that have yielded 100,000 tons of ore by the end of 1928.*

	Mine.	District or State in which situated.	Year of commencement of work.	Total production to end of 1923.
1	Balaghat . . .	Balaghat . . .	1901	1,478,292
2	Thirori . . .	Do. . . .	1902	1,271,223
3	Kandri . . .	Nagpur . . .	1900	1,098,595
4	Chikhla (with Yedarbuchi).	Bhandara . .	1901	962,311
5	Kachhi Dhana . .	Chhindwara . .	1906	828,795
6	Mansar . . .	Nagpur . . .	1900	799,604
7	Kodegaon . .	Do. . . .	1903	468,394
8	Gumgaon . . .	Do. . . .	1901	425,989
9	Sitasaongi . .	Bhandara . . .	1908	344,256
10	Lohdongri . .	Nagpur . . .	1900	330,573
11	Miragpur . . .	Balaghat . . .	1905	325,354
12	Garajhor . . .	Gangpur . . .	1908	309,986
13	Sukli . . .	Balaghat . . .	1905	304,996
14	Ramrama . .	Do. . . .	1906	260,322
15	Kajlidongri . .	Jhabua . . .	1906	223,546
16	Ukua (with Samnapur and Gudma).	Balaghat . . .	1906	215,306
17	Ramdongri . .	Nagpur . . .	1901	201,053
18	Kurmura (with Ponwar Dongri, Dongri Buzurg, Balapur Hamesha).	Bhandara . . .	1902	186,438
19	Netra (with Gola Hurki).	Balaghat . . .	1908	165,156
20	Satak . . .	Nagpur . . .	1904	158,730
21	Shodan Hurki . .	Balaghat . . .	1912	148,247
22	Junawani . . .	Nagpur . . .	1906	132,115
23	Manegaon . . .	Do. . . .	1902	131,113
24	Kosumba . . .	Balaghat . . .	1905	125,114
25	Kacharwahi . .	Nagpur . . .	1902	119,944
26	Mandri . . .	Do. . . .	1902	111,693
27	Jamrapani . .	Balaghat . . .	1906	95,406

or less continuously for nearly 6 miles. In an earlier review a thickness of 100 feet (of ore) was ascribed to the Kandri deposit, and of 1,500 feet (ore and gonditic rocks) to the Ramdongri deposit. Subsequent work indicates that both these deposits are folded, and there is no evidence that the ore-bodies are anywhere more than 45 to 50 feet thick: a greater apparent thickness appears to be due to repetition by folding. On the other hand the ore-band is often much thinner, but may have again attained a fictitious thickness due to folding. The depth to which these ore-bodies extend is unknown. It is, however, almost certain that, in many cases, they extend to at least 100 to 400 feet below the outcrop, *e.g.*, some of the deposits occupying hills in the Central Provinces; and it is very probable that some of the Central Provinces deposits extend to depths considerably greater than these; for the evidence obtained indicates that the deposits were formed in depth, so that the position of the deposit bears no genetic relation to that of the surface. An idea of the size of some of these deposits can be obtained from the amounts of ore they have yielded, as shown in Table 75.

The total production from deposits of the gonditic type (the C. P., Jhabua, and Gangpur) averaged 675,472 tons annually during the quinquennium as compared with 525,192 tons annually during 1919-23, 504,597 tons annually during 1914-18, and 529,152 tons during 1909-13.

Composition of ores.

The typical ores of the Nagpur-Balaghat area of the Central Provinces consist of mixtures of braunite and psilomelane of different degrees of coarseness of grain. The most typical ore is a hard fine-grained ore composed of these two minerals. Other minerals found in the Central Provinces ores are hollandite, vredenburgite, sitaparite, and rarely pyrolusite. The unique ore of Sitapar in the Chhindwara district consisting of hollandite with sitaparite and fermorite, proved to be a surface form, and at a depth of 60 feet gave place almost entirely to braunitic ore, which persisted to the bottom of the pit at 100 feet (see page 221). The ores exported from the Central Provinces are mainly of first grade, but during the quinquennium moderate quantities of second-grade ores (43 to 48 per cent. of manganese), and small quantities of low-grade ore (42·5 per cent. of manganese) have

been produced. The chief characteristics of the first-grade ores are the high manganese contents (usually 48—54 per cent. as exported), moderately high iron (usually 4—8 per cent.), rather high silica (usually about 6—9 per cent. and largely due to the braunite in the ore), and moderately low phosphorus (usually about 0·07—0·20). For analyses see Table 68, page 207. At Dongri Buzurg in the Bhandara district, an ore rich in peroxide is found.

Ores in crystalline limestones.

In addition to the deposits found in association with spessartite- and rhodonite-bearing rocks in the Central Provinces, manganese-ores are sometimes found in association with crystalline limestones, usually containing piedmontite, and also regarded as of Dharwar age. Ores of this character are found characteristically in the Nagpur and Chhindwara districts. The manganese-ores occur either as lines of nodules or as fairly definite beds in the limestone, the latter being the rarer mode of occurrence. In most cases it is not found profitable to work these ores; but where the bed of ore is of greater thickness than usual, as in the Junawani forest, it may pay at times of high prices; whilst patches of residual nodules accumulated during the dwindling of limestones will pay to work at any time, if not too far removed from transport facilities. The ores found thus are usually composed of braunite and psilomelane or hollandite. These ores, and the associated crystalline limestones and calcareous granulites, are probably the products of the metamorphism of calcareous sediments with associated manganiferous ores, and are thus analogous in origin to the ores associated with the true gonditic rocks.

The remarks in the foregoing paragraphs apply particularly to the deposits found in the Central Provinces, but also in a general way to the deposits found associated with rocks of the gondite series in other parts of India. A few remarks about these are given below.

Gangpur, Bihar and Orissa.

During 1908, the extension of the gondite series into Bihar and Orissa was proved by the discovery of manganese-ore deposits in Gangpur State associated with rocks containing spessartite and rhodonite. The ores are typical gonditic ores, containing braunite in a matrix of psilomelane. The chief deposit, Gariajhor, has yielded 309,986 tons of ore during the years 1908 to 1928. As will be seen

from the figures summarised in the following table, the quality of the ore is similar to that of the Central Provinces :—

—	1909.		1919-1923.	
	Limits of analyses.	Mean of analyses.	Average analysis of ore railed.	
Manganese	47·64 — 54·13	50·53	49·60	45·85
Iron	5·53 — 6·35	5·85	7·82	8·29
Silica	2·6 — 8	5·7	4·96	5·04
Phosphorus	0·018— 0·143	0·089	0·205	0·144
Moisture	0·78 — 1·16	0·96	..	..

The 1909 figures relate to cargoes shipped during that year, the manganese and phosphorus figures representing eight anaylses on a total of 3,600 tons of ore, and the other constituents four analyses on a total of 1,600 tons of ore. The 1919-23 figures, supplied by Mr. W. H. Clark, represent the first- and second-grade ore as exported during the period. The estimated average figures for 1924-28 are given in Table 68. These two sets of figures are of interest as illustrating the increase of phosphorus contents in gonditic ores with depth from the surface.

Narukot, Bombay.

Rocks of the gondite series with associated manganese-ore have been found in a small hill at Jothvad in Narukot State, Bombay. The occurrence is of no economic importance, but of great scientific interest. The rock surrounding the hill is a porphyritic biotite-granite presumably of Archæan age, and apophyses from this pierce the gonditic rocks of the hill. Isolated pieces of gonditic rock are included in the granite, and amongst these inclusions are pieces of manganese-ore, proving that a portion at least of the manganese-ore had been formed before the time of intrusion of the granite into the Dharwar rocks of the area.

Panch Mahals.

Manganese-ore deposits are being worked near Shivrajpur and Bamankua in the Panch Mahals. The rocks with which they are associated are Champaners, that is Dharwars; no rocks of gonditic nature have been found in this area, but it seems, judging from reports, that although a portion of the ores has certainly been formed by the superficial replacement of quartzites, a portion may have been deposited contemporaneously with the enclosing Dharwar rocks; in this case the deposits may be classified with the gonditic deposits. The absence of gonditic rocks would then mean that the rocks—as at the Bala-

ghat deposit in the Central Provinces—had not been subjected to such intense metamorphism as that which produced the gonditic rocks associated with most of the Central Provinces deposits. 860,691 tons of ore have been won from this area in the twenty-three years 1906 to 1928. The average composition of this ore as exported is shewn in Table 69.

Jhabua, Central India.

The chief deposit in Jhabua State was that situated at Kajlidongri. This is a true gonditic occurrence, and the rocks associated with the manganese-bearing rocks are those known as Aravallis, which are in this part of India the equivalents of the Dharwars. In the 12 years 1903 to 1915, this deposit yielded 195,763 tons of manganese-ore, and since 1916, the deposit has been abandoned. During 1921 to 1928, 27,783 tons of ore have been extracted, making a total of 223,546 tons. For the quality of the ore obtained see Table 68.

B.—The Kodurite Group.

Kodurite series.

The kodurite series [1] is developed typically in the Vizagapatam district, where it occurs associated with other Archaean crystalline rocks, the chief groups of which are the khondalite series including the calcareous gneisses or granulites, the gneissose granite, and the charnockite series. The kodurite series was held to be of igneous origin, and probably of later age than the khondalite series, which is the series with which it is closest associated. The original koduritic magma has been differentiated into a series of rocks ranging from very acid (quartz-orthoclase-rock) through basic (kodurite) to ultra-basic (spandite rock and manganese pyroxenites). The typical rock, *kodurite*, is composed of potash-felspar, spandite (a garnet intermediate in composition between spessartite and andradite), and apatite. The manganiferous nature of these koduritic rocks has been a petrological surprise, and it has consequently later been suggested [2] that they may be hybrid rocks produced by the assimilation by an acid igneous magma of manganese-ore bodies and manganese-silicate-rocks allied perhaps to the gondite series.

The manganese-bearing minerals contained in these rocks are spandite, rhodonite, and two or three other manganiferous pyroxenes,

[1] *Mem. Geol. Surv. Ind.*, XXXVII, Chaps. XII, XIII, (1909); *Rec. Geol. Surv. Ind.*, XXXV, p. 22, (1907); *op. cit.*, XLII, p. 208, (1912); *op. cit.* XLIII, p. 42, (1913).

[2] *Rec. Geol. Surv. Ind.*, XLVI, p. 102, (1915). Also see Whitman Cross; *Journ. Geol.*, XXII, pp. 791—806, (1914).

at present unnamed. Subsequently, the whole series of rocks has been chemically very much altered with the production, from the felspar, of enormous masses of lithomarges and, from the manganiferous silicates, of manganese-ores. Other secondary products are chert, ochres, and wad.

Vizagapatam : mode of occurrence.

The manganese-ore bodies thus formed are often extremely irregular both in shape and size, often showing no definite strike or dip. But in other cases, as at Garbham, the ore-bodies have a well-marked dip and strike, and apparent bedding, which probably represents original banding in the parent rock; for much of the ore has been deposited so as to replace metasomatically the pre-existing rock.

Dimensions of ore-bodies.

Some of the ore-bodies are of very large size. The largest, Garbham, is some 1,600 feet long, and 167 feet thick at its thickest section, 100 feet of this thickness being ore and the remainder lithomarge, wad, etc. From the commencement of work on this deposit in 1896, to the end of 1928, Garbham has yielded the large total of 908,679 tons of ore. The only other very large deposit in this district is Kodur; but this is really a series of scattered ore-bodies in lithomarge. It has yielded 396,598 tons of ore from 1892 to 1928, of which only 4,007 tons was produced in the quinquennium 1924-28. It was the first manganese-ore deposit to be worked in India.

Composition of ores.

The ores of the Vizagapatam district are composed mainly of psilomelane with subordinate amounts of pyrolusite, braunite, manganmagnetite, and in one case (Garividi) vredenburgite. They are usually of second and third grade—although some first-grade ore has been obtained at Kodur—and can be divided into manganese-ores (above 40 per cent. Mn.) and ferruginous manganese-ores (below 40 per cent. Mn.). They are characterised by high iron and phosphorus contents, and comparatively low silica (see Table 69).

C.—The Lateritoid Group.

Lateritoid deposits.

In several parts of India manganese-ore deposits are found on the outcrops of rocks of Dharwar age, associated with the latter in such a manner as to leave little doubt that the ores have been formed by the replacement at the surface of Dharwar schists, phyllites, and quartzites,

The masses of ore thus formed do not consist entirely of manganese-ore, but often contain considerable quantities of iron-ore; and every gradation is to be found from manganese-ores, through ferruginous manganese-ores and manganiferous iron-ores, to iron-ores. The masses of ore thus formed are often more or less cavernous and bear considerable resemblance to ordinary laterite. In fact some geologists would designate such occurrences by this term; but others would object: and, therefore, to obviate this difficulty the term *lateritoid*—meaning *like laterite*—has been introduced to designate this class of deposits. Lateritoid deposits are, then, irregular deposits of iron and manganese-ores, occurring on the outcrops of Dharwar rocks, and resembling in their cavernous and rugged aspect masses of ordinary laterite. When the rock replaced is a schist or phyllite, it is usually found altered to lithomarge below the capping of ores. The mineral composition of the ores thus formed is usually fairly simple. The manganese-ores are pyrolusite, psilomelane, wad, and more rarely pseudo-manganite, and manganite; whilst the iron-ores are limonite and earthy hematite. The harder crystalline minerals—braunite, vredenburgite, sitaparite, magnetite, and specular hematite—are found rarely or never in the lateritoid ores. Hollandite may sometimes occur. The chemical characteristics of the manganese-ores are high iron, low silica, and often very low phosphorus. The manganese is usually correspondingly low, so that the ores won consist mainly of second-grade manganese-ores and third-grade ferruginous manganese-ores. Such deposits will be worked to the greatest advantage when a market can be found for the iron-ores and manganiferous iron-ores, as well as for the manganese-ores.

Singhbhum and Jubbulpore.

The areas where ores of this nature have been found are given on page 222. Singhbhum and Jubbulpore, and in 1923, Keonjhar State, have yielded small quantities of merchantable ore, but the most important of the lateritoid areas are Sandur and Mysore. A large number of deposits, many of them of large size, have been located in the Sandur hills, mostly perched up on the edge of the hills at an average elevation of about 1,000 feet above the plains. When transport difficulties have been surmounted, these deposits may be expected to yield large quantities of second-grade and third-grade ores, with possibly a certain proportion of first-grade ore from the Kamataru portion of the state. The deposits are being worked by the General

Sandur.

Sandur Mining Company, Ltd. During the years 1905 to 1914, 418,424 tons of ore were won from these deposits, mainly from the Ramandrug and Kannevihalli areas, but work was closed down during the war on account of the high ocean freights. In 1921, work was resumed by this company and 39,355 tons of ore were extracted during the quinquennium ending 1923. 451,709 tons during the present quinquennium making a total of 915,486 tons since the beginning. For analyses see Tables 68 and 69.

Mysore.

The manganese-ore deposits of Mysore are numerous, but very few of them can compare in size with those of the Sandur hills, although they have been formed in the same way. The chief exception is the Kumsi deposit in the Shimoga district, from which some 160,000 tons of ore were won in the three initial years 1906 to 1908, the state as a whole yielding 228,243 tons during the same period. In the quinquennium 1909-13, there was a great decline in output compared with that of the initial period of work, the average annual output of the state being 28,286 tons. The subsequent decline has been at a much smaller rate, the average annual output for the quinquennia 1914-18 and 1919-23 being respectively 24,205 tons and 21,703 tons. There has been a slight recovery during the present quinquennium, the average annual output being 32,046 tons. The reduction of the industry to the lower level of the last 20 years is largely due to the superficial nature of the deposits leading to early exhaustion of the best class of ores, whilst high railway and sea freights prevent the exploitation of the lower-grade ores. The chief company at work in this state is the United Steel Companies, Limited, which took over the Workington Iron Company, Ltd., in 1918.

D.—The Laterite Group.

Goa and Belgaum.

Manganese-ores are sometimes found in true laterite: but such ores are rarely of much economic value. The ores of Goa (Portuguese India) occur in part in this way (in low-level laterite), as also those of Belgaum (in high-level laterite). They are not economically of great importance owing to the irregular manner in which they occur, and their extremely variable composition. Picked ores, however, are similar in composition to the picked lateritoid ores. Only 154 tons of ore won in Goa were exported from Marmagao during the period 1919-23 as compared with 598 tons during the war period and 16,243 tons

in the previous quinquennial period. These exports are, of course, excluded from Table 59. A production of 14,612 tons of ore has been extracted from Belgaum for the years 1925 to 1928.

No figures have been obtained of the production of manganese-ore in Goa during the present period.

Mica.

(Cyril S. Fox.)

Introduction.

The mineralogical aspects of mica are given in all text-books of mineralogy. Reference to such works will show that there are several varieties of mica, and that a characteristic property of most micas is a highly developed cleavage whereby thin sheets or films of mica can be readily produced. The chief micas of commercial value are those which are practically transparent in relatively thin plates. These may be pale-tinted and clear or only slightly stained and spotted. The two chief varieties of commerce are *muscovite* and *phlogopite.* With the exception of a very small production of phlogopite from the workings in Travancore, nearly all the mica extracted from the pegmatitic rocks of the mica occurrences of India belong to the variety known as muscovite.

Exports.

For the past 30 years India has been a great exporter of mica. Practically all the mica obtained from Indian mines is despatched to Europe and America. During the past decade, 1919-28, the average annual exports of Indian mica has been upwards of 72,000 cwts. (the average annual exports during the quinquennium, 1919-1923, was 58,600 cwts. and during 1924-28 over 86,000 cwts). These exports, as will be seen later, total almost twice the recorded output of the mines, and, in consequence, it is difficult to gauge the domestic consumption of mica. It has been estimated that the amount of cut mica, chiefly the larger sizes (above No. 4's), utilised in India, is less than 2,000 cwts. annually, but this estimate is obviously a guess, as no detailed returns appear to be available. Nevertheless, it may be assumed that practically all the mica produced from Indian mines and prepared in the form of cut mica, usually as mica splittings, is exported.

The exported quantities of Indian mica are shown in the accompanying tables, which show the exports of Indian mica during the periods 1919-1923 and 1924-1928, and to whom consigned—

TABLE 76.—*Exports of Indian Mica during 1919-1928.*

—		1919	1920	1921	1922	1923	1924	1925	1926	1927	1928
Blocks . . .	Cwts.	(a)	(a)	4,011	9,001	12,401	15.258	14,952	15,822	14,259	12,413
	Rs.	(a)	(a)	18,42.469	17,80.494	16,46,944	23,81.623	33,21,061	34,04,390	32.82,248	30.81,539
Splittings . . .	Cwts.	(a)	(a)	17,651	34,144	70.895	54,837	84,747	74,125	63,229	83,066
	Rs.	(a)	(a)	32,15,314	40,04,751	64.29,578	65,67,545	73,12.062	75,95,678	59,81,724	62.73,407
TOTAL	Cwts.	**53,098**	**76,517**	**(b) 30,944**	**43,145**	**83,296**	**70,095**	**99,699**	**89,947**	**77,488**	**95,479**
	Rs.	86,34,480	1.06.54.380	63.94,113	57.85,245	80.76,522	94.49 168	1.06 33,123	1.10,00,077	92,63.972	93,54,946

(a) Separately recorded since April 1921.

(b) Details of block and splittings are incomplete. The total figure represents exports during nine months, April to December, 1921.

TABLE 77.—*Destination of exported Indian Mica.*

Whither consigned.		1919	1920	1921	1922	1923	1924	1925	1926	1927	1928
United Kingdom	Cwts.	54,177	46,300	19,376	15,905	20,213	27,114	36 118	31.618	38.298	42,556
	Rs.	79 26 330	61,42,050	36 39.165	24,47,925	24,14.177	37,24.951	50.01,385	44,13,886	43 00 239	45,91,826
United States	Cwts.	3 872	27,056	8.304	18,234	52,856	31,923	39.928	17.038	18.410	23,968
	Rs.	6 17.580	41,89,380	22,69,075	23.56.501	46 29,368	44.82.793	35 40.048	51 94,255	30,73 548	22 80,370
Germany	Cwts.	..	..	1,469	5,752	5 822	4.578	16 905	4 984	11 014	15.236
	Rs.	..	..	1,90,193	5.56,819	4,64,449	3.73,819	11 43,975	3,97,105	8,09.478	11 11,340
France	Cwts.	.	..	..	..	..	1,179	1.186	1,340	3,876	3,983
	Rs.	..	..	..	..	..	2,91.213	2.14,049	2.69,630	3,71 246	4,29,509
Other countries	Cwts.	1.049	3,161	1,795	5 254	4.375	5.301	6.072	4,967	5,890	9,686
	Rs.	99 570	3.22,950	2,95,680	4 24,000	5.77,528	5,71,872	7.33,666	7,25,201	6.49,461	9,82,392

It is evident from these returns that the export trade in Indian mica has, on the whole, sensibly increased. It is also clear that the highest values declared for these exports correspond to the years when the exports are lower than the average for each quinquennial period. Owing to the lack of details regarding the sizes and qualities of the mica exported, either as block mica or mica splittings, it is impossible to follow the true fluctuations of the demand; but taken as a whole for each year, the declared values of the consignments have varied as follows: in 1919, the average value works out to a little over Rs. 146 per cwt. (roughly Rs. 1-5-0 per lb.); in 1923, it was nearly Rs. 97 per cwt. (about Rs. 0-13-10 per lb.); in 1924, the value was roughly Rs. 135 per cwt. (nearly Rs. 1-3-3 per lb.); and in 1928, nearly Rs. 98 per cwt. (nearly Rs. 0-14-5 per lb). These are declared values at the time of export and, for the past decade, may be assumed at, roughly, Re. 1 per lb. However, these computations are not a true index of the prices actually obtained by the vendors. In the Bihar 'mica belt', mica may be purchased locally at prices considerably lower, perhaps, than Re. 1 per lb. (on lots of mixed cut mica). Brokers in Europe and America pay more than Re. 1 per lb. exclusive of freight. Finally, the consumers in Europe and America are believed to pay on an average Rs. 3 per lb. inclusive of freight, etc., for the material they buy at relatively short notice.

Value.

In Table 78 the production, in long tons, of mica from all countries is shown for the period 1919 to 1928. From these returns it is clear that the tonnage of mica produced and exported from India is barely 25 per cent. of the world totals of the last few years. This is largely due to the fact that no scrap mica is recorded in the Indian production. The only mica of which statistics are available from India is that known as block mica and mica splittings of sizes from one square inch upwards. In other countries, particularly in the United States of America, large quantities of low grade mica find a sale in the preparation of mica powder, etc. The value of this low grade material is small. To show how great is the value of the mica obtained and despatched from India it has been thou t justifiable to revive a Table 79 showing the value of mica raised in the three principal producing countries—India, Canada and the United States during the past 20 years from 1909 to 1928. It should, however, be pointed out that the production from the Union of South Africa has, since, 1924, grown to important dimensions until this country as shown in Table 78 is now third on the list of great producers.

Value of world output.

TABLE 78.—*World's production of Mica during the years 1919 to 1928.*

(Long tons.)

Producing Country.	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928
British Empire.										
Northern Rhodesia	..	1	..	..	..	..	1	4	8	4
Southern Rhodesia	5	87	78	59	81	134	130	183	(a) 183	183
Tanganyika Territory	..	(b) 27	(b) 3	(b) 11	(b) 32	55	68	52	42	33
Union of South Africa	9	6	2	1	14	892	1,054	1,130	1,660	3,572
Canada (shipments)	(d) 2,459	(c) 1,966	(c) 627	(c) 2,990	3,147	3,653	3,589	2,272	2,445	3,196
India (exports)	2,955	3,826	(e)1,547	2,157	4,165	3,505	4,985	4,497	3,874	4,774
Australia	..	1	..	4	..	2	4	11	5	25
Ceylon	(b) 8	(b) 15	(b) 5	1	1	..	..	..	..	..
TOTAL	5,436	5,929	2,260	5,223	7,440	8,211	9,831	8,129	8,217	11,787
Foreign Countries.										
France (lithium mica)	..	..	..	..	..	..	..	246	(f)	(f)
Germany (lithium mica)	..	..	..	..	..	..	493	654	(f)	(f)
Norway (exports)	..	31	..	..	..	..	23	41	8	84
Rumania	..	133	..	..	..	..	..	..	..	..
Portugal (lithium mica)	..	..	..	..	..	..	(f)	184	379	(f)
Russia	..	..	(f)	8	..	..	190	478	1,496	96
Sweden	..	..	..	8	5	4	93	52	10	12
Madagascar	..	49	152	91	102	281	282	325	497	625
United States (sales)	(g) 3,948	5,862	2,632	6,411	8,112	4,856	9,457	7,258	6,282	5,902
Argentine (exports)	..	269	145	63	100	118	117	83	75	(f)
Brazil (exports)	152	67	45	66	55	78	64	51	39	74
Japan	..	..	..	15	424	582	1,065	(f)	(f)	(f)
Korea	..	..	..	..	11	23	20	16	(f)	(f)
Mexico	..	(h) 4	..	..	..	..	..	..	..	
Guatemala	..	(h) 4	..	..	..	..	16	12	7	(f)
Spain	7	5	2	..	3	..	..	..	..	..
TOTAL	4,107	6,424	2,976	6,662	8,872	5,942	11,820	9,400	8,793	6,793
GRAND TOTAL	9,543	2,353	5,236	11,885	16,312	14,183	21,651	17,529	17,010	18,580

(a) In addition 19 tons of lithium mica were produced. (b) Exports. (c) Sales. (d) Output. (e) For April to December, 1921. (f) Not available.
(g) Production in short tons. (h) Imports into U. S. A. from the country specified.

TABLE 79.—*Value of Mica raised in the three principal producing countries during the twenty years 1909 to 1928:.*

—	Canada.	India (*a*).	United States of America.	Total.	India's per cent. of this total.
	£	£	£	£	
1909	30,345	154,978	57,603	242,926	63·79
1910	39.093	188,983	69,219	297,295	63·56
1911	26,422	207,778	73.060	307,260	67·62
1912	29,564	341,349	68,151	439,064	77·74
1913	34,931	302,564	89,540	427,035	70·85
TOTAL	160,355	1,195,652	357,573	1,713,580	..
Average	*32,071*	*239,130*	*71,515*	*342,716*	*69·77*
1914	22,410	191,066	67,801	281,277	67·92
1915	18.885	208,496	88,106	315,487	66·08
1916	25,180	341,255	122,139	488,574	69·84
1917	44,803	575,285	155,624	775,712	74·16
1918	55,147	598,971	157,185	811,303	73·82
TOTAL	166,425	1,915,073	590,855	2,672,353	..
Average	*33,285*	*383,015*	*118,171*	*531,471*	*71·66*
1919	56,260	750,824	111,302	918,386	81·75
1920	77,267	1,065,438	146,715	1,289,420	82·63
1921	15,768	426,274	36,034	478,076	89·16
1922	31,288	385,683	63,361	480,332	80·29
1923	67,189	538,435	90,594	696,218	77·33
TOTAL	247,772	3,166,654	448,006	3,862,432	..
Average	*49,554*	*633,331*	*89,601*	*772,486*	*81·99*
1924	73,415	679,796	61,497	814,708	83·44
1925	53,727	799,483	101,818	955,028	83·71
1926	47,098	820,901	110,311	978,310	83·91
1927	35,729	691,341	66,294	793,364	87·14
1928	16,887	698,130	(*b*)84,980	799,997	87·26
TOTAL	226,856	3,689,651	424,900	4,341,407	..
Average	*45,371*	*737,930*	*84,980*	*868,281*	*84·98*

Average for 20 years . . . . 77·00.

(*a*) Export values.

(*b*) Estimated.

Since the period of the Great War, largely as a result of the demands of the electrical industry, there has been an immense increase in the consumption of mica splittings, chiefly of sizes No. 5 and smaller. The larger sizes (No. 4 up to Special) have a limited but steady market, as seen in the above Table 76. The proportion, by weight, of mica splittings to block mica is as much as 6 to 1. On the other hand, block mica is nearly half the value of mica splittings (inclusive of the cost of splitting); in other words, the value of block mica is nearly 3 times that of the splittings. One must, however, remember that the former is in larger sizes. It may be mentioned here that the manufacture of micanite—built up sheets of mica from splittings glued with shellac—has now almost entirely ceased in India.

Block mica and splittings.

During the quinquennium, 1919-1923, there was a decided falling off in the exports of Indian mica to the United Kingdom—India's best market. Since 1924, these exports have steadily increased, until the returns of 1928 show that that market is once more the largest consumer of Indian mica. In the intervening period, 1922-1926, America was the biggest buyer of Indian mica. The American imports centred in New York, and it is to be presumed that the United States were the chief users. During the last quinquennium Germany and France have become important purchasers of Indian mica.

Chief consumers.

The method of recording the output of mica from the mines needs explanation. The figures supplied by various mining companies and other producers are the totals of all the cut mica obtained in their cutting and sorting sheds. No details are given, and there seems to be no mention of the rough mica from which the cut mica is obtained. In such circumstances, there must be considerable confusion if the rough mica is purchased from small vendors and cut and sold by dealers who have no mines and who, consequently, send in no returns a condition which appears to prevail at present and which, from a statistical point of view, is unsatisfactory in every way. As seen in the accompanying table of production (Table 81), the output of Indian mica (from the mines) is less than half the mica exported from India. It is true that there is a small import trade in mica (see Table 80), but this does not affect the situation. There is no doubt that the exports of Indian mica are double the recorded production from the mines.

Production.

By far the greater quantity of mica is obtained from the workings in the so-called Bihar mica belt, which trends across parts of the districts of Hazaribagh, Gaya and Monghyr. Almost all the mica from that region finds its way down to Calcutta and is shipped from that port. The output of mica from the Nellore mines of Madras is normally exported from the port of Madras, while the annual production from Travancore, Mysore, and Rajputana usually finds its way to Bombay, where it is finally shipped for export abroad. Bihar and Orissa being the largest producer of mica, as seen from the table of production, it is evident that the exports will be largest from the port of Calcutta.

Localities.

During the last eight years there are returns (see Table 80 below) which show that a certain amount of mica—chiefly block mica—has been *imported* into India from the United Kingdom, the United States, and Japan. In view of the brisk demand for mica splittings it is to be concluded, therefore, that this mica, whether it be Indian mica returned to this country or foreign mica, has been received for conversion into fine splittings and would then be re-exported as splittings of Indian mica. The production of fine splittings by hand is an art which is performed to perfection in India and is carried out at considerably less expense than would be possible in European countries.

Imports.

TABLE 80.—*Imports of Mica during 1921 to 1928.*

		1921	1922	1923	1924	1925	1926	1927	1928
Blocks	cwts.	3,187	1,951	3,204	1,429	4,654	918	1,568	337
	Rs.	*5,93,593*	*1,83,936*	*2,21,122*	*1,84,912*	*5,61,680*	*1,60,045*	*1,42,567*	*60,912*
Splittings	cwts.	845	56	267	89	96	256	76	443
	Rs.	*1,44,961*	*15,559*	*10,414*	*21,080*	*10,906*	*54,618*	*7,910*	*17,028*
TOTAL	cwts.	4,032	2,007	3,471	1,518	4,750	1,174	1,644	780
	Rs.	*7,38,554*	*1,99,495*	*2,31,535*	*2,05,992*	*5,72,586*	*2,14,663*	*1,50,507*	*77,940*

In no available publication has there been any adequate discussion of the complexities of the Indian mica trade, and particularly of that large proportion of it which originates in the mines of Bihar (Hazaribagh) and is sent overseas, *viâ* Calcutta. It has been hinted on several occasions that the discrepancy between the recorded output of the mines and the export returns is chiefly due to the wholesale dealing in mica—especially in the area between Kodarma and Giridih. The number of convictions for theft of mica show that several mining companies, usually the larger ones, must suffer loss from pilfering. Their mines are in lonely forest areas, their stores are occasionally two miles away, and the transport of the days output (bundles of *rough* mica) is generally made after dusk. It is impossible to guess how large is the leakage *en route* if the guards connive at the traffic. The receivers of this stolen mica may or may not be owners of small mines; they may not be classed, unrestrictedly, with the many vendors of *cut* mica (either dressed block-mica or splittings), from whom local purchases can be made openly. The local dealing in mica is of long standing and has frequently been of considerable convenience even to the biggest vendors; it has enabled them to procure certain sizes and qualities of mica to meet orders which they could not have met from their own mines. In the existing circumstances it would be almost impossible for a vendor to state precisely the source of origin of his mica, even if he were pressed to do so. Thus, in a sense, all *purchasers* of mica may or may not be open to the charge of illicit mica buying.

Illicit dealing.

The local Government of Bihar and Orissa, in consultation with the Director of the Geological Survey and the Chief Inspector of Mines, framed certain rules which aimed at restricting the illicit trade in mica. When these measures were placed before the provincial Legislative Assembly they were rejected and, consequently, did not become law. The bill has since been emended in various details and is now being presented again. By a proper system of granting licenses (in addition to the usual mining leases), it is hoped to introduce some kind of control in the buying and selling of mica in Bihar. The prohibition against transporting mica by night has also received due consideration. The subject has been threshed out with care. Judging from the export trade it is evident that the mica industry is in a flourishing condition, and any injudicious interference may result in a serious

Mica Bill, 1927.

TABLE 81.—*Production of Mica in India during 1919 to 1923 and 1924 to 1928.*

Province.	1919		1920		1921		1922		1923	
	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*
	Cwts.	*Rs.*	Cwts.	*Rs.*	Cwts.	*Rs.*	Cwts.	*Rs.*	Cwts.	*Rs.*
Bengal	..	..	..	..	..	..	..	..	..	..
Bihar and Orissa	34,230·2	*15,96,781*	32,883·5	*16,28,707*	26,058	*12,67,815*	29,400·8	*10,49,573*	23,813	*11,76,476*
Central Provinces	..	..	0·3	*12*	..	..	100	(*a*)	..	..
Delhi (?)	..	..	..	..	..	..	..	..	..	..
Gwalior	..	..	..	..	..	..	..	..	..	..
Madras	8,320·6	*5,25,800*	11,927·8	*6,14,414*	4,376	*2,10,445*	1,301·2	*95,481*	8,814	*3,38,615*
Mysore	..	..	55·2	*2,125*	182	*4,273*	135·7	(*a*)	(*b*) 48·7	*1,757*
Rajputana	3,232·9	*75,845*	2,085·7	*1,05,517*	1,872	*1,11,033*	940·4	*57,650*	1,179·5	*71,097*
TOTAL	45,783·7	*21,98,426*	46,952·5	*23,50,775*	327,488	*15,93,566*	31,878·1	*12,02,704*	33,855·2	*15,57,945*
Value in sterling		*£191,167* (£1 = Rs. 11·5)		*£235,077* (£1 = Rs. 10)		*£106,238* (£1 = Rs. 15)		*£80,180* (£1 = Rs. 15)		*£105,863* (£1 = Rs. 15)

(*a*) Not available.
(*b*) Excludes 370·7 cwts. of rough mica.

TABLE 81.—*Production of Mica in India during 1919 to 1923 and 1924 to 1928*—contd.

Province.	1924		1925		1926		1927		1928	
	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*
	Cwts.	*Rs.*	Cwts.	*Rs.*	Cwts.	*Rs.*	Cwts.	*Rs.*	Cwts.	*Rs.*
Bengal	..	..	..	..	4	*233*	..	..	..	..
Bhiar and Orissa	28,736	*14,49,600*	30,210	*14,85,876*	29,325	*15,08,539*	31,564	*17,44,623*	35,148	*18,176,426*
Central Provinces	..	..	..	..	..	..	..	..	..	..
Delhi (?)	20	*28*	..	..	..	..	..	..	..	..
Gwalior	..	..	120	*3,303*	320	*10,548*	240	*7,431*	140	*6,877*
Madras	11,273	*5,47,348*	14,779	*6,46,004*	11,584	*6,43,684*	9,546	*6,32,986*	3,947	*4,87,396*
Mysore	15	(*a*)	163	*10,080*	..	..	..	..	..	..
Rajputana	864	*61,941*	718	*54,253*	691	*56,363*	1,264	*67,015*	882	*39,800*
TOTAL .	**40,908**	*20,58,917*	**45,990**	*21,99,516*	**41,924**	*22,19,367*	**42,614**	*24,52,055*	**45,112**	*24,10,499*
Value in sterling .		*£148,123* (£1= Rs. 13·9)		*£165,377* (£1= Rs. 13·3)		*£165,624* (£1= Rs. 13·4)		*£182,989* (£1= Rs. 13·4)		*£179,887* (£ 1= Rs. [illegible]·4)

(*a*) Not available.

set back. At the same time, if no active measures are taken to protect the bigger producers, their operations may prove unprofitable. Although India holds the premier position as a producer of of mica, she has not the monopoly she once had. The demands of consumers are more exacting than they were and it is doubtful if the Indian mica industry would long retain its present prosperous position once the larger mining companies were obliged to close down owing to excessive leakage and consequent loss of profit.

Indian mica occurrences.

The chief mica mining areas in India are those of Hazaribagh in Bihar and of Nellore in Madras. Mica has also been obtained from workings in the Eranial *taluk* of Travancore, the Hassan district of Mysore and Ajmer in Rajputana.

The 'mica belt' of Bihar obliquely traverses the districts of Gaya, Hazaribagh and Monghyr, along a strip about 12 miles broad and over 60 miles long. A large number of the more important workings are situated either in, or in the vicinity of, the Kodarma forest. The local names of Kodarma, Domchanch, Dhab, Gawan, Tisri, etc., are familiar to mica dealers in London and elsewhere. By far the larger proportion of the Indian output of mica is obtained from the Bihar mica-belt, although the mica is often commercially spoken of as Bengal mica or Bengal ruby mica[1] because the sheets in sufficient thickness have a beautiful ruby colour—a characteristic of the muscovite from the Hazaribagh district. Another but secondary characteristic of the area is the fact that garnets found in association with mica in Bihar occur in the crystal habit known as the icositetrahedron.

The mica mines of the Nellore district of Madras are situated on the eastern half of the Madras coastal plain between latitudes 14 and 15, over a tract of country some 60 miles long and 8 to 10 miles broad. As in the Bihar belt, where beside primitive burrowings there are modern mines, so in the Nellore district, although the great majority of the mines are merely open quarries, Tellabodu, Kalichedu and some other mines are worked on up-to-date lines. Madras mica generally has a characteristic green colour thought to be due to traces of chromium in the muscovite from that area. However, brown mica, not unlike ruby, occurs at Kalichedu and along the pegmatite strike there. Associated with the mica are,

[1] Dating from the days before the province of Bihar and Orissa was formed.

as will be seen below, several minerals, amongst which are to be seen garnet crystals in the dodecahedral habit. The garnets of both Nellore and Hazaribagh are of the same variety although they have different crystal shapes.

The distinction, which is apparent in the prevalent methods of working in Bihar and Madras, is also noticeable in the preparation of mica for the market in the two areas. In the Bihar belt all the mica is sickle-trimmed into irregularly shaped blocks, while the Nellore mica is trimmed by shears into rectangular shapes and classified and sized with meticulous care for excise purposes. The Bihar block mica is thicker than the shear-trimmed Madras material.

There is a great similarity in the mode of occurrence of mica in pegmatites throughout India and it is thought that a description of the mining operations undertaken by the Geological Survey of India at Jorasemar near Kodarma on behalf of the Ministry of Munitions, London, may not be out of place. The workings were opened late in 1917, and closed under the charge of the writer in 1919.

Government mica mines, Jorasemar.

The prevailing rocks at Jorasemar are varieties of mica-schist in a narrow strip which terminates about $1\frac{1}{2}$ miles to the east of Jorasemar camp. The mica-schist band is about a mile broad from north to south at the camp itself and trends away westward to join the large area of mica schists in the Government Reserve forest north of Kodarma. At Jorasemar the mica-schists appear to lie in a synclinal fold of the gneisses of Bihar. The foliation strike of both gneisses and mica-schists is invariably E—W. The foliation dips are usually very steep (frequently vertical), in some exposures northward and in others to the south. Local variations in strike and dip are by no means uncommon—anticlinal pitching folds, evidences of puckering and apparent thrust-faulting in miniature being often observed at various places.

Irregular, elongated, lenticular outcrops of pegmatite traverse both the gneisses and mica-schists. There is usually a parallelism between the strike of the pegmatites and the foliation planes of the enclosing gneisses or schists. Pegmatites may, however, traverse the foliation planes obliquely or even at right angles. As a result of experience the local miners have discovered that it is useless, as a rule, to look for mica of workable quantity and quality in those pegmatites which traverse the gneisses or in those schists which are markedly non-

micaceous. Most of the marketable mica of the Hazaribagh district appears to be won from pegmatites traversing mica-schists. It does not stand to reason that all pegmatites which traverse mica-schists are worth exploiting. They are not. Each pegmatite varies in the value of its marketable mica-content and the latter can only be determined by actual exploration. The tendency, therefore, is to associate the mica, which is worth mining, with areas in which mica-schists occur and to prospect pegmatites which traverse these mica-schists. This association holds good in many parts of the district.

The pegmatites of Jorasemar have been found to be exceedingly erratic both in continuity and shape. They have, however, one common feature, and this is that, though keeping a rough parallelism with the foliation planes of the enclosing mica-schists, they pitch or plunge down, at a slant to the dip of the foliation plane, in a direction always towards the west, *i.e.*, away from the point where the schists themselves pinch out. None of these pegmatites have a greater thickness than 15 feet, and of those which have been worked to any considerable extent, few continue more than 100 feet without change in strike, dip, thickness or in the richness or quality of their mica-bearing contents.

The area contains many pegmatites, some worthless from a mining point of view, others remarkably prolific in certain portions of the pegmatite. Some of the larger pegmatites are clearly associated with lines of faulting and special buckling of the schists, the faulting being shown by slickensided surfaces. The faults appear to have been formed before the larger mica crystals had developed, for the crystals though at times badly buckled and cleaved could not have survived the intense contortion to which the schists owe their origin without complete destruction from a marketable standpoint.

Enrichments of mica are not uniform throughout the section of a pegmatite, nor are the minerals composing the pegmatites equally disposed. Pockets of isolated crystals of muscovite mica invariably occur to one side or other of the body of the pegmatite. The central mass of the deposit is usually composed of a core of granular, pelucid quartz in which beryl and tourmaline crystals may be totally enclosed. On each side of the quartz core there is usually a margin of felspar and it is, most frequently, at the junction of this felspathic margin and the central quartz core that the largest

'books' of mica are found. Marketable mica is also to be found in certain pegmatites near the actual contact with the schists, either on the hanging-or foot-wall side. Large crystals of garnet occur in about the same situation while tourmaline is common in the margin and in the quartz core. Apatite in varying quantities is found in almost every one of the larger pegmatites.

It was hardly possible to say from day to day how a working was going to turn out in the next three or four days, and this state of uncertainty continued to the day of closing down the mines. Out of at least 100 places, which were either taken over from petty contractors, or re-opened from a disused condition, or started from new ventures, only five showed comparative steadiness for any length of time from the day they were put in working order.

As most of the pegmatites were of no great size, in nearly all cases each working place required its own entrance and separate arrangements for hoisting and pumping. In the larger pegmatites, the shape and position of the rich mica-bearing portion were usually found to be so disposed that it was difficult to arrange for more than three or four working places.

The production of large quantities of mica, other things being equal, depends entirely on the number of productive working places. If the development has to be done on numerous small pegmatites, as detailed above, then working costs will be greater than those of the exploitation of an equal number of working faces in a single large pegmatite.

At Jorasemar the production simply depended on finding and opening up more and more working places. As labour became available the output steadily rose and the maximum output would have been reached when every possible workable pegmatite had been opened or when the maximum permissible expenditure was being incurred. Practically no machinery was found necessary other than that worked by hand. Buckets and hand-pumps were found sufficient in dealing with the small quantities of water that accumulated in the workings. Shear-legs, a swinging derrick, a capstan, three crab winches and a few single sheave pulley-blocks comprised the most complicated forms of hoisting apparatus necessary for these simple mines.

In proportion to the development work, somewhat large quantities of explosives were used. Small and frequent charges of 40 per cent. dynamite were utilised in loosening the matrix in which the larger crystals of mica were embedded. These 'shots' were so fired as to leave the mica undamaged and yet save the

laborious chiselling that would otherwise have been necessary to get out the 'books' intact. Candles were exclusively used for lighting. There was also a heavy wear on the drills owing to the practice of prising up rock loosened by 'shots'; breakages became so frequent that a portable forge had to be placed near the more distant workings and the sirdars warned that crowbars were to be used in place of chisels. Timbering was occasionally necessary in the mines, especially when working in the neighbourhood of slickensided surfaces. The mouths of many of the shafts had also to be secured by '**collar sets**', but most of the shafts were safe if thatched shelters were built over them to prevent rain beating in.

The rough books of mica were split or cleaved into thick plates at the mines and the worthless pieces thrown away. After hand-picking the plates were tied into bundles of about 50 lbs. weight each and carried to the godown where they were weighed and stored, the bundles of large mica being kept separate from the small or '*ruddi*' bundles.

Each morning rough mica was issued to the cutters for sickle-trimming. Useless pieces were cut away, flaws removed and rough-dressed plates of block mica obtained. On an average 100 cutters, of varying degrees of efficiency, were able to deal with 50 *maunds* of Jorasemar mica and produce 10 *maunds* of sickle-dressed ruby (S. D. B.) block. The waste is, therefore, nearly 80 per cent. of the mica brought from the mines. To obtain 20 per cent. of cut mica is considered a very good performance; the average of the district varied from 10 to 14 per cent.

The cost of cutting varies. Good cutters or sickle-dressers get as much as nine to ten annas a day while women, working less efficiently, earn three to four annas daily. The average cost at a rate of Re. 0-6-6 works out to about Rs. 4 per *maund* of cut mica obtained.

The sickle-dressed or cut mica was next sized in the sorting department to the following scale:—

	Square inches.
Specials	36 to 48
No. 1	24 to 36
No. 2	15 to 24
No. 3	10 to 15
No. 4	6 to 10
No 5	3 to 6
No 5½	2½ to 3
No. 6	1 to 2½
No. 7 (a)	Less than 1

(a) This small size has been utilised comparatively recently.

The following table gives the percentage proportion of the various sizes and qualities obtained by sorting from a month's supply about 400 *maunds* of cut (S. D. B.) mica.

Quality.	Clear.	Slightly stained.	Fair stained.	Stained.	Waste.
Size.					
Specials	*nil*	0·005	0·010	0·005	0·100
No. 1	0·015	0·040	0·020	0·045	0·150
No. 2	0·035	0·090	0·055	0·200	0·150
No. 3	0·080	0·160	1·00	0·260	0·250
No. 4	0·380	0·800	0·480	1·380	0·300
No. 5	1·100	2·000	0·900	6·000	0·650
No. 5½	0·640	1·300	0·020	4·200	0·350
No. 6	1·600	4·700	0·200	65·500	1·050
Rough films	Total .	4·000		Total waste.	3·000
S. D. films	Total .	4·680			

The above figures may, therefore, be taken as representing a true practical test, so that for every 100 *maunds* of cut unsorted mica only 88 *maunds* were shipped as block (S. D. B.) and some 8½ *maunds* were available as films for local sale. This 100 *maunds* of cut mica represents the cutting of 500 *maunds* of rough mica. For every 2 *maunds* of rough mica brought to the godown nearly 1 *maund* is discarded in picking while making up the bundles at the mine; 750 *maunds* of mined mica, therefore, give 100 *maunds* of cut unsorted mica.

The average mica contents of the workable portions of pegmatites varies greatly—from 3 to 10 per cent. with an average of about 6 per cent. of mica in the total rock excavated; this works out to less than 1 per cent. of cut or marketable mica from the rock excavated. It would represent a very low grade ore in a metal ore mining proposition. Unlike the mining of other minerals where every particle of the substance is valuable it is the quality as well as the size of the product mined which is of importance in mica

mining. The objective is to produce the largest possible quantity of clear sound mica. It should be free from flaws, cracks or other deleterious defects and in as large pieces as possible. Frequently large 'books' of mica are obtained, 1 to 2 feet across, out of which it is perhaps impossible to get a single piece of stained Number 6, owing to the heavily stained, flawed and buckled condition of the plates, or to '*jatai*' by which is meant an interlocking of cleavage plates so that the laminæ are stuck together and do not easily come off or split into the clean-surfaced thin sheets known as splittings.

From the 'sizers', 8 of whom can easily handle 10 *maunds* of cut mica per day, the sized mica is passed to the 'graders'. Twenty graders should deal with 10 *maunds* of sized mica in a day. In the process of separating out the various qualities small cracks or flaws or a film or two have frequently to be removed from the mica plates. There is thus a slight loss in waste and the production of some films. Nine *maunds* of mica worth shipping out of 10 *maunds* was the proportion obtained at Jorasemar with ½ *maund* S. D. films and ½ *maund* of waste.

Formation of mica pegmatites.

Holland (*Mem. Geol. Surv. India,* XXXIV, Pt. 2, p. 28) gives the following analyses of Indian mica (Bengal muscovite) :—

	(i) Per cent.	(ii) Per cent.
SiO_2	45·57	45·71
Al_2O_3	36·72	36·57
Fe_2O_3	0·95	1·19
FeO	1·28	1·07
MgO	0·38	0·71
CaO	0·21	0·46
K_2O_3	8·81	9·22
Li_2O	0·19	..
Na_2O	0·62	0·79
F	0·15	0·12
H_2O	5·05	4·83
	99·93	100·67
Sp Gr	2·831	2·830

In the majority of cases biotite is also present in association with muscovite-bearing pegmatites. This black mica, however, is not at present utilised; it contains a larger percentage of FeO (16 per cent.) but less H_2O (2 per cent.) than muscovite. The other associated minerals in a mica-bearing pegmatite are massive granular quartz, coarse aggregates of orthoclase (microcline) felspar, tourma-

line, garnet (common iron), apatite and beryl. In certain rare cases samarskite (Sankara mica mine), pitchblende and monazite have been found (Abraki Pahar, Gaya district). The degree of coarseness in the texture of the pegmatitic constituents indicates quiescent conditions suitable for slow crystallisation. The pegmatites stand in striking contrast with the mica-schists and gneisses in which they occur. These rocks are nothing like so coarse-textured; their minerals are orientated parallel to the foliation planes and there is abundant evidence of buckling, puckering and crushing. The most careful scrutiny fails to discover any thermal metamorphism at the contact between the pegmatite and the enclosing schists. In some cases the pegmatites are known to form simple lenses in the schists entirely unconnected with any larger mass of pegmatite. Many of the larger pegmatites have been proved to have no connection, other than perhaps the plane of a fault, with any other pegmatite and certainly with no granitic intrusion in the immediate vicinity.

From the above-mentioned facts and data it is evident that in the majority of cases the mica-bearing pegmatites of Jorasemar are not, primarily, of igneous origin. The field evidence points to these lenticular masses of coarse-textured granitoid rock as being the re-crystallised products of the mica-schists themselves. The digestion and re-crystallisation has, however, been localised to certain particular parts of the metamorphic schists. Careful investigations at Jorasemar appeared to indicate that such re-crystallisation was best developed in the arches and troughs of folds, in certain fault zones where great crushing took place, or at places where, although no appreciable dynamic forces developed, the static pressures must have been very large. In these circumstances one is led to the possibility that many of the pegmatites of the mica-schists of Bihar and Madras are a large scale representation of the phenomena, carried to completion, so evident in the 'spotted slates, which so often mark the beginning of change in argillaceous sediments since in these we see the process arrested at an early stage.' (Harker, 'Natural History of Rocks,' p. lxxi).

Uses of mica.

It is unnecessary to state in detail the various purposes for which mica is required. Sheet mica has been largely used for stove and furnace windows, for gas lamp chimneys and shades, etc., but the chief use is for electrical purposes as an insulator, *e.g.*, for separating commutator segments in dynamos, for electric heaters and cookers, in electric condensers,

as washers in sparking plugs, bolts and screws, etc. Formerly size No. 5 was the smallest piece of sheet mica utilised; during the war the utility of smaller sheets (Number 6) was demonstrated, and now size Number 7 is a marketable product. This is largely due to the development of the micanite industry. Micanite is really the built-up sheets of the smallest, thinnest films of mica which are cemented together with shellac dissolved in spirit. The 'made' sheets can be built to any size and thickness. They require to be steamed, pressed and rolled and can in the pressing be moulded to almost any desired shape.

Mention was made of the fact that, although India is the largest producer of mica in the world, practically the whole output is exported. Attention was also drawn to the fact that mica splittings are most cheaply and efficiently made in India. When it is remembered that India holds a monopoly in the production of shellac it is difficult to understand why this country does not hold a predominant position in the manufacture of micanite.

There are numerous published papers which deal with the mica occurrences of India, the British Empire and other countries, and with questions of the marketing of mica generally. Amongst these are the Quinquennial and Annual Reviews of mineral production by the Director of the Geological Survey of India (published in the Records of the Department); Sir Thomas Holland's monograph on Mica (*Mem. Geol. Surv. Ind.*, XXXIV, Pt. 2); T. H. LaTouche's Annotated Index of Indian Minerals of Economic Value; Dr. J. Coggin Brown's compilation of the trade and marketing of mica (Bull. No. 15, Indian Industries and Labour); the brochure on 'Mica' issued by the Imperial Mineral Resources Bureau; a pamphlet on 'Mica' by Oliver Bowles (Serial No. 2357, Reports of Investigations, Bureau of Mines, Department of the Interior, U. S. A.); and a 'Note on the Marketing and Utilization of Mica' by G. Vernon Hobson (Bull. No. 40, Indian Industries and Labour) and also his paper 'Mica and its International Relationships' (*Trans. Inst. Min. Met.*, Vol. XXXVI, 1927, pp. 337—395).

Conclusion.

Mr. Hobson's note above referred to is probably the most valuable contribution by an inspecting officer on the subject of the utilisation of Indian mica. He made a careful examination of the mica occurrences in India and subsequently (1927) continued his investigations in the United States, Canada and Great Britain. In the United States

his enquiries extended to some of the largest consumers of mica. In Canada he visited the following phologopite mica mines:—the Lacey mine, near Sydenham, Ontario, and the Blackburn mine in the neighbourhood of Buckingham, near Ottawa. In Great Britain, besides consulting various large consumers, he followed the writer's example by visiting the great micanite works at Walthamstow. With this experience and knowledge, Mr. Hobson, in a considered summary (Bull. No. 40, Indian Industries and Labour, 1928, p. 17), says:—'To summarise the situation, it appears reasonably certain that the market for mica will be a steadily increasing one and that the demand for splittings will increase at the expense, to some extent, of that for block mica.'

'The Indian position in the market is still one of great strength, the increase in the demand for splittings contributing very considerably to this strength. The demand frequently made by consumers for Indian mica only, is often based, not on any intrinsic superiority of Indian mica over that from other countries, but on the more satisfactory grading and marketing of the product. It is pointed out, however, that other countries are now alive to these facts and the Indian producer must not, because of the commanding hold India has on the market, be led to relax his efforts, instead he should by constant attempts improve the condition in which his product is marketed, so as to offset the growing competition from other countries.'

'It is necessary that immediate steps should be taken, by the proper authority, to ensure the protection against illegitimate trading that the producer may fairly look for, and thereby dissipate the feeling of doubt as to the security of future Indian supplies that is spreading among consumers; for consumers may otherwise turn their attention to other sources of supply.'

'The producer, when thus protected should, as the owners of the natural asset have a right to expect, turn his attention to more up-to-date methods of exploitation and should no longer be content, or be allowed, to remove the superficial mica in the cheapest possible way, if thereby the hazard and expense of future work be increased.'

'At present the elimination of the broker does not appear practicable, but producers by the avoidance of certain business methods and practices, as enumerated, can do much to foster direct trading. With the elimination of mutual distrust amongst producers and the growth of a spirit of mutual help the development of a scheme of

co-operative marketing appears to offer distinct possibilities; whilst trade propaganda to encourage the wider use of mica appears to be a logical amplification of the publicity work undertaken by the mica-plate manufacturing firms, which only partially covers the field.'

Monazite.

[E. H. PASCOE.]

Uses.

Monazite, an anhydrous phosphate of the rare earths of the cerium group, including especially cerium, lanthanum, neodymium, praseodymium, yttrium and erbium, owes its economic value to the small and variable percentage of thorium oxide which it contains. Although a market is being developed for some of the other rare earths in special types of arc-lamp electrodes and in the manufacture of special optical glasses, the thoria content is that which gives the mineral its commercial importance. This thoria constitutes the raw material in the preparation of thorium nitrate used in the manufacture of incandescent gas mantles. The percentage of thoria in monazite varies between 1 and 12, but mineral containing less than 3½ per cent. cannot be used remuneratively in the manufacture of thorium nitrate.

Sources of the world's supply.

Up to the year 1895, the whole of the world's supply of monazite was derived directly or indirectly from the Carolina deposits worked principally by the Welsbach Light Company of New York. In 1895, the sands of the Brazilian coast were first worked by the German Thorium Syndicate and the Austrian Welsbach Company and caused keen competition. The Brazilian deposit being very uniform and considerably richer and more easily available than the Carolina deposits, the American company was forced to suspend operations in May, 1910, and practically the whole demand was met by the German and Austrian companies under agreement together. Owing to its occurrence on the sea-shore of Brazil and the very low cost of transport, the German Thorium Syndicate was able to lower the market price of thorium very considerably in spite of the fact that they paid, according to report, about half their profits in royalties to the Government of Brazil. Most of the production from the ore was exported to Germany.

The Brazilian industry, being in the hands of Germans and Austrians, declined as soon as the War broke out, and in 1916 the production was *nil*. The recovery subsequent to that year was of a spasmodic nature. In 1920, the last year for which figures are available, the Brazilian output amounted to 1,153 metric tons, but in the previous year the amount was only 146 tons. The average for the four years 1919-22 was about 437 metric tons; since 1923 no production has been reported but quantities up to 200 long tons were exported. The United States industry was always very small and no statistics have been published since 1917; a small export of gas mantles has however persisted.

Travancore monazite.

Early in the century monazite was proved by the Imperial Institute to occur in association with the much more valuable thorianite and thorite in Ceylon. The total production of thorium-bearing minerals from that country, however, up to and during 1922, amounted only to some 311 tons. In 1909, monazite-bearing sands were discovered by Mr. C. W. Schomburg of the London Cosmopolitan Mining Syndicate on the Travancore coast. Mr. Tipper, who inspected the deposits, states that the mineral is known with certainty to occur in pegmatite intrusions but is probably mainly derived from the gneisses of the Travancore hills. The mineral occurs in small, round, amber-coloured grains varying from 0·1 to 0·2 millimetre in diameter. Its density is 5·191 and its refractory index is also very high. The best means for identification in the field is a Browning direct-vision spectroscope in which the didymium lines can be observed. The mineral forms one of the constituents of the sands along the sea-shore, and contains between 8·8 and 10·08 of thoria. India possesses by far the largest reserves of monazite known in the world, and these, as regards quality measured in terms of thoria contents, are superior to any others. In certain places selective action by the waves on the sands has led to the concentration of large quantities of monazite. By mechanical means this sand can be further concentrated.[1] Work was commenced in 1911, by the London Cosmopolitan Mining Company. This was replaced by the Travancore Minerals Company who as a result of the War had been purged of their German interests. Thorium Limited also held a concession, but ceased operations during the quiquennium under review. Messrs. Hopkins & Williams are still producing.

[1] *Rec. Geol. Surv. Ind.*, Vol. XLIV, p. 286 (1914).

During 1921, the production figure reached 1,260 tons, valued at nearly £31,000, but fell to 1 cwt. in 1925. The decline in the monazite industry has been world-wide and due to the supplanting of incandescent mantles for gas-lighting by electricity. There has been an appreciable revival since 1925, due to the increasing demand for ilmenite (*q. v.*), a mineral associated with monazite and obtained as a kind of by-product with the collection of the latter. The average annual output of monazite in India for the past five years amounted to 214 tons worth £3,060; the whole of it goes to London, New York and Hamburg.

The output and value of the past 10 years are shown in the following table:—

TABLE 82.—*Production of Monazite in Travancore State.*

Year.	Quantity.	*Value.*
	Tons.	£
1919	2,023·7	*60,712*
1920	1,641	*49,231*
1921	1,260	*30,959*
1922	125	*1,871*
1923	246·3	*3,697*
1924	622·3	*9,301*
1925	(*a*)	..
1926	64·2	*947*
1927	280·0	*3,810*
1928	103·4	*1,242*

(*a*) The production amounted to 1 cwt. only.

Monazite also occurs in the sands to the east of Cape Comorin, in the Tinnevelly district and again near Waltair in Vizagapatam.

Other Indian localities.

A crystalline variety containing only $2\frac{1}{4}$ per cent. of thorium has been found in pegmatites of the Bangalore district, Mysore State.[1]

More recently a large number of beautiful crystals of this mineral have been found with pitchblende and columbite in pegmatites in the Gaya district, Bihar and Orissa.[2] It has also been found in minute quantities in concentrates from Tavoy and Mergui.[3]

Thorianite?—A black mineral doubtfully identified with thorianite has been discovered at Thadagay hill, Travancore. The mineral is apparently isometric. The specific gravity is extremely high, namely 10·03. Owing to the paucity of material a partial analysis only could be made, and this gave as the principal constituents, thoria 32·3 per cent. and uranium oxide 40 per cent. The identity with thorianite is very doubtful and it might easily be a variety of uraninite. More is required to be known of this interesting find.

Petroleum.

[E. H. Pascoe.]

Total production.

During the five-year period 1914-18, the total production of petroleum in the Indian Empire exceeded that of the preceding quinquennium by some 212 million gallons. During 1919-23, there was a further total increase of $84\frac{1}{3}$ million gallons. The quinquennial period under consideration shows a decrease of over $45\frac{1}{2}$ million gallons, fulfilling thus the forecast made in the Review for 1919-23 (*Rec. Geol. Surv. Ind.*, Vol. LVII, p. 254). The peak years of earlier periods were:—1916, with a production of 297,189,787 gallons; 1919, with a production of 305,749,138 gallons; and 1921, with a production of 305,683,227 gallons. In spite of the fall in

[1] Mineral Resources of the Mysore State, p. 191.
[2] *Rec. Geol. Surv. Ind.*, Vol. L, p. 255 (1919).
[3] *Ibid*, Vol. XLVIII, p. 179 (1917).

average output in the 5 years under review, the last year, 1928, was responsible for a record production of 305,943,711 gallons; the prestige of this year was, however, discounted by a fall in value. Taking value in rupees as a criterion, 1922 holds first place with the figure Rs. 10,80,37,412 (Rs. 15=£1); taking value in sterling as the criterion, 1920 leads with the figure £8,017,820 (£1=Rs. 10). The value figure for 1928 was only Rs. 5,78,10,387 (£4,314,208) (£1=Rs. 13·4). The average annual production during 1924-28 was about 290⅓ million gallons, against an average of 299½ million gallons during the previous 5 years. If the intensive drilling carried on during 1928 be continued, it will be possible to maintain or raise this average figure during the next five years.

The world's production.

India still contributes only a very small proportion of the world's marketed supply; in 1923, it was 0·83 per cent.; in 1928, only 0·685 per cent. In 1924, India stood 8th on the list of petroleum-producing countries of the world; in 1928, she had dropped to 11th place, having been overtaken during the intervening years by Columbia, Peru and Argentina. There seems every prospect of her being further ousted by Trinidad.

The outstanding features of the past five years were: the rapid decline in Mexico, whose output in 1927 was less than half what it had been in 1924; the enormous rise in the United States figure during 1927 (133 million barrels, *i.e.*, the equivalent of 4,655,000,000 Imperial gallons or India's *total* production for the past sixteen years!); the continued rapid restoration of Russian output to pre-war figures; the enormous stride in Venezuela from 9 million barrels in 1924, to seven times that figure in 1927, and second place in the world's list of producers in 1928; a doubling of their production on the parts of Roumania and Argentina. The United States of America have now adopted a conservative policy, and this is likely to have a restraining effect upon the world's production figure in the early future. The States, nevertheless, contributed over 67 per cent. of the world's supply in 1928, mostly from the mid-continent and the Californian fields. The decline in Mexico was due largely to adverse legislation. In 1928, Venezuela was responsible for over 8½ per cent. of the world's supply, and Russia—third on the list—for about 6¼ per cent. Mexico comes fourth on the list and Persia fifth. The Dutch East Indies, with the support of the growing Sarawak field, stands sixth, followed in order by Roumania, Columbia, Peru, the Argentina, India and Trinidad.

TABLE 83.—*Production of Petroleum in India during the years 1924 to 1928.*

—	Quantity.		Value.	
	Gallons.	*Metric tons* (*a*)	Rs.	£.
1924	294,571,692	1,183,019	*10,50,73,342*	(*b*) 7,559,233
1925	289,606,542	1,163,078	*10,29,51,666*	(*c*) 7,740,727
1926	280,369,326	1,125,981	*9,78,93,827*	(*d*) 7,305,509
1927	281,113,909	1,128,972	*5,92,47,675*	(*d*) 4,421,468
1928	305,943,711	1,228,689	*5,78,10,306*	(*d*) 4,314,207
Average .	*290,321,036*	*1,165,948*	*8,45,95,379*	*6,268,229*

(*a*) The metric ton is assumed to be equivalent to 249 Imperial gallons of crude petroleum, of an average specific gravity of about 0·885.
(*b*) £1=Rs. 13·9.
(*c*) £1=Rs. 13·3.
(*d*) £1=Rs. 13·4.

The world's consumption of petroleum has been increasing by leaps and bounds and, should aviation ever become the craze that motoring has, the exhaustion of the supplies of the natural fluid is well within sight. Attention is being directed more and more towards oil shale and there is little doubt that this and the exploitation of natural petroleum by mining methods will be the immediate remedies for the coming shortage. The enormous size of the oil shale deposits in the world is insufficiently realised, and the amount of crude oil ultimately obtainable therefrom is probably many times the ultimate total supplies of the natural fluid[1]; the United States is again the favoured country in this respect. The final remedy for the exhaustion of mineral oil will consist of oils and alcohols derived from vegetable or possibly animal sources, but there is little chance of such substitutes becoming in any way competitors with natural petroleum or with oil shale for many years to come. The natural

World's consumption.

[1] Presidential Address, Mining and Geological Inst. of India, *Trans.*, Vol. XIX, pp. 19—50 (1924).

supplanter of the liquid mineral will be oil shale and the process of supplanting will most probably commence within the next 30 years.

Consumption of all forms of mineral oil is still on the increase in India and there persists a large market in India and Burma for foreign oil, which has to pay an import duty.

Import duties.

From the 1st March, 1922, up to and including 1924, the duty on motor spirit and kerosene was $2\frac{1}{2}$ annas per gallon. On the 1st April, 1925, the duty on motor spirit was raised to 4 annas and remained at this rate until the 28th February, 1929; the rate on kerosene remained the same throughout the period. Up to the 1st April, 1926, jute-batching oil, lubricating and fuel oil of a flash-point of over 150°F. paid an import duty of $7\frac{1}{2}$ per cent. *ad valorem*. Since the above date jute-batching oil has paid a duty of Rs. 10 a ton, and lubricating oil a duty of 1 anna 4 pies per imperial gallon, the duty on fuel oil remaining constant, *i.e.* at $7\frac{1}{2}$ per cent. *ad valorem.*

The average annual imports of foreign mineral oil into India during the financial years 1918-19 to 1922-23 amounted to

Imports.

117,241,203 gallons valued at Rs. 7,07,21,197, and showed an increase of about $27\frac{1}{2}$ million gallons over the average annual imports during the previous five years. The average annual imports during the period under review amounted to 194,518,757 gallons, valued at Rs. 9,42,61,445, indicating an increase of over $77\frac{1}{4}$ million gallons. The imports have, in fact, shown a steady expansion—with an interruption during 1926-27—from a little under 169 million gallons in 1923-24 to nearly $232\frac{1}{2}$ million gallons in 1927-28. The chief feature of the period under review is the steady increase of imports from Persia at the expense of those from the United States. Whereas between 1918-19 and 1922-23, the United States of America headed the list of India's suppliers with a contribution of 40 per cent. of the total, and Persia stood second with a contribution of 32·4 per cent., positions between 1923-24 and 1927-28 were reversed and Persia now stands first with a contribution of 38·2 per cent., the United States supplying only 34·8 per cent. The expansion of the Persian output was foretold in previous quinquennial reviews. The amounts supplied by Borneo show a steady increase which, however, has not kept pace with the increase from Persia and other countries.

TABLE 84.—*Origin of foreign Mineral Oil imported into India during the years 1923-24 to 1927-28.*

Countries.	1923-24		1924-25		1925-26		1926-27		1927-28		Average.	
	Gallons.	*Per cent. of total.*	Gallons.	*Per cent. of total.*	Gallons.	*Per cent. of total.*	Gallons.	*Per cent. of total.*	Gallons.	*Per cent. of total.*	Gallons.	*Per cent. of total.*
Borneo . .	31,126,821	*18·4*	26,156,526	*13·9*	36,312,957	*18·1*	33,266,231	*18·1*	39,038,458	*16·8*	33,180,199	*17·0*
Persia . .	60,102,418	*35·6*	77,743,336	*41·5*	72,097,870	*36·0*	66,647,878	*36·3*	95,753,806	*41·2*	74,469,062	*38·2*
United States of America.	57,977,343	*34·3*	71,106,659	*38·0*	72,289,996	*36·1*	71,201,585	*38·8*	62,496,999	*26·9*	67,014,516	*34·8*
Other countries	19,695,901	*11·7*	12,270,473	*6·6*	19,708,703	*9·8*	12,451,262	*6·8*	35,148,561	*15·1*	19,854,980	*10·0*
TOTAL .	**168,902,483**	*100·0*	**187,276,994**	*100·0*	**200,409,526**	*100·0*	**183,566,956**	*100·0*	**232,[illegible]37,824**	*100·0*	**194,518,757**	*100·0*
	Rs.		Rs.		Rs.		Rs.		Rs.		Rs.	
Value . .	*8,39,55,142*	..	*9,35,11,067*	..	*10,05,10,829*	..	*8,89,19,552*	..	*10,44,10,633*	..	*9,42,61,445*	..

TABLE 85.—*Annual value of Mineral Oil imported during the years 1923-24 to 1927-28.*

Countries.	1923-24	1924-25	1925-26	1926-27	1927-28	Average.	*Average value per gallon.*
	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	As.
Borneo	1,23,93,103	1,06,35,897	1,47,48,543	1,26,78,353	1,64,07,580	1,33,72,695	*6·43*
Persia	1,15,44,739	1,50,84,068	1,45,97,914	1,31,62,839	2,16,07,644	1,51,99,441	*3·27*
United States of America . .	4,56,51,274	5,60,17,934	5,56,61,681	5,40,57,535	4,61,09,510	5,14,99,587	*12·30*
Other countries	1,43,66,026	1,17,73,168	1,55,02,691	90,20,825	2,02,85,899	1,41,89,722	*11·43*
TOTAL .	8,39,55,142	9,35,11,067	10,05,10,829	8,89,19.552	10,44,10,633	9,42,61,445	*7·75*

The values of the imported mineral oil during the period under review are shown in Table 85; the average annual value was Rs. 9,42,61,445, as compared with an average of Rs. 7,07,21,197 for the previous period. It should be noticed that in this table the United States is a very easy first, which means that although its contribution was less than that of Persia, the value of the oil supplied greatly exceeded that of the latter country. The average value per gallon of the oil supplied by America was, in fact, nearly four times the average value per gallon of that supplied by the latter country. The average value per gallon of all oil imported during the five years under consideration was As. 7·75 as compared with As. 9·65 in the previous five years.

Value of Imports.

The annual exports of oil shewed a marked decrease compared with the figures for the previous quinquennium, and amounted, in fact, to less than one-third of the latter; read in conjunction with the large increase in imports ($77\frac{1}{4}$ million gallons) and the decline in production (9 million gallons), this means that India is rapidly increasing her consumption of mineral oil and is replacing her own deficiencies more and more from outside sources. The exports of paraffin wax increased by 263,696 cwt. (see Table 86).

Exports.

TABLE 86. *Exports of Mineral Oil and Paraffin Wax during the years 1924 to 1928.*

Year.	Mineral Oil.	Paraffin wax.
	Gallons.	Cwts.
1924	22,387,938	588,140
1925	12,816,274	629,860
1926	2,345,360	812,460
1927	154,478	954,000
1928	140,755	993,520
Average	7,568,961	795,596

Occurrence of Indian petroleum.

The petroleum resources of the Indian Empire are confined to the sites of three ancient gulfs:

(1) The Burmese gulf, covering what is now the basins of the lower Irrawaddy and its main tributary the Chindwin and opening southward into the Bay of Bengal.

(2) The Assam gulf occupying the middle portion of the present Brahmaputra and debouching into the Bay of Bengal *viâ* the modern Meghna basin; and

(3) The Punjab-Baluchistan gulf extending along the base of the Himalaya northwestward from a point opposite Naini Tal, and curving round through the Potwar plateau south-southwestwards through what are now the Baluchistan hill ranges, to the Arabian sea.

In all three areas the oil is associated with Tertiary strata, and has had probably similar conditions of origin in all cases. In Burma it is known to occur in beds of Nummulitic age, but by far the greater number of seepages and all the fields of importance are in the next highest geological series, to which there is every reason to suppose the oil is indigenous. In Assam oil is found in a similar series. In the Punjab on the other hand it is the Nummulitic which is the predominant oil-yielding series, and although the only supplies which have so far proved of economic importance are found in the series above, there is good reason to suppose that the oil has migrated up from the Nummulitic below. Whether in Burma, Assam or North-West India, the occurrences of petroleum are always connected with an anticlinal structure. In the Yenangyaung field, the best known field of Burma, conditions have been ideal. The area lies on a N.N.W.-S.S.E. flat anticline, the axis of which by variation in pitch has produced a flat dome in the Kodaung tract. The rocks in this dome include several porous sands at various depths, each covered by an impervious clay-bed, which has helped to retain the oil until the impervious layers are pierced by artificial means.

The provincial production of petroleum in India is shown in Table 87.

TABLE 87.—*Provincial production of Petroleum during the years 1924 to 1928.*

Provinces.	1924	1925	1926	1927	1928
	Gallons.	Gallons.	Gallons.	Gallons	Gallons.
Burma . .	270,213,003	262,828,930	250,040,471	245,904,044	262,187,263
Assam . .	12,975,249	18,730,412	24,098,535	24,542,265	31,502,288
Punjab . .	11,383,440	8,047,200	6,230,320	10,667,600	12,254,160
TOTAL, gallons	**294,571,692**	**289,606,542**	**280,369,326**	**281,113,909**	**305,943,711**
Total, metric tons	*1,183,019*	*1,163,078*	*1,125,981*	*1,128,972*	*1,228,689*

Punjab.

With regard to the Punjab, the Khaur field possesses a structure as favourable as that of Yenangyaung and is being successfully exploited. In many parts of the Punjab, however, and in the Baluchistan area the strata have been too tightly folded, or the rock-folds have been too deeply truncated by agents of denudation or have been dislocated by earth-movements, and much of the original stores of oil have disappeared: oil seepages are common enough, but many of them seem to be mere 'shows' unconnected with reservoirs that can be tapped by artificial means.[1] In the Punjab, seepages or 'oil springs' have been known for many years to exist in the Rawalpindi district and further to the south-west, but the total output of the province up to 1915 was negligible. From that year onwards, however, owing to the development of the Khaur field in the Attock district, the figure, though small at first, began to assume serious proportions, and will almost certainly expand still more in the near future. In 1918, it rose to over $\frac{3}{4}$ million gallons, but no really big stride was made till 1922, when over $7\frac{1}{3}$ million gallons were produced; in 1923, this output was increased to over $11\frac{3}{4}$ million gallons. Then, followed a decline, due partly to water trouble, to under $6\frac{1}{4}$ million gallons in 1926. In 1927 and 1928, there were substantial rises, the production in the latter year being $12\frac{1}{4}$ million gallons.

The chief features regarding exploratory work in the Punjab were the continued want of success in the boring operations on the neighbouring Dhulian dome. The Burmah Oil Company in 1925, finally abandoned their test in the Khairpur state after boring to the greatest depth at which any likelihood of production was thought possible. A boring put down by the Whitehall Petroleum Corporation near Jhatla, and 8 miles south-west of Talagang, is interesting as having, in the opinion of the Corporation's geologists, pierced the entire local sequence of Chinji, Kamlial and Murree beds and to have entered the underlying Nummulitic; although the great depth of 6,007 feet was reached, traces only of oil were encountered, and none was struck in commercial quantity. The Whitehall Petroleum Corporation, after many years of expensive geological investigation and exploratory prospecting, have given up and left the country. The Attock Oil Company's refinery in Rawalpindi was first opened in 1922. It has a capacity of some 80,000 gallons

[1] E. H. Pascoe: Petroleum in the Punjab and N W. Frontier, *Mem. Geol. Surv. Ind.*, Vol. XL, pt. 3 (1920).

per day but is capable of extension, should this prove necessary. Petrol, kerosene, Diesel engine oils, lubricating oils of all descriptions, paraffin wax and candles are all manufactured at the Company's plant.

Baluchistan.

Attempts to develop the oil resources indicated by seepages in different parts of Baluchistan have not yet proved successful. The most prominent of these are near Khatan in the Mari hills and Moghal Kot[1] in the Sherani country, where small oil occurrences are known. The Moghal Kot area forms a very open anticlinal fold with a pitch of its axis towards the E.N.E. Unfortunately, the anticline coincides more or less with the gorge of a river, by which much at any rate of any oil previously present must have been liberated. In the Khatan area some dozen wells were drilled by Government many years ago, two of which reached depths between 1,100 and 1,400 feet; production never rose beyond a few thousand gallons a month. A shallow well was also drilled at each of the places, Kirta, Spintangi, Chhappar Rift,[2] and Sukkur.[3] The Kirta area is again being tested by the Burmah Oil Co., who are also putting a boring down in the western Bugti hills.

Assam.

The most prominent oil occurrences in Assam are those in the Lakhimpur district and at the southern foot of the Khasi and Jaintia hills. Systematic drilling has been conducted at Digboi in the Lakhimpur district for the past 35 years by the Assam Oil Company, Ltd. During the last two or three years, the refinery has been extended, and the production of crude oil, in consequence, considerably increased. Geological investigations by the Assam Oil Company's staff have aroused expectations of a successful extension of the Digboi field. The results of prospecting operations at Dhekiajuli, Dilli and Burragolai have been disappointing; oil was obtained in the Burragolai well, but the quantity was insufficient to be of commercial importance. With regard to the Surma Valley area, 57 wells have been drilled on the Badarpur field in Cachar with disappointing results. Drilling difficulties are unusually great, the decrease in yield from the wells is unusually rapid, and the deeper tests—over 3,000 feet—which at first aroused hopes, have shown the same

[1] *Rec. Geol. Surv. Ind.*, Vol. XXV, p. 171 (1892).
[2] *Ibid.*, Vol. XXV, p. 116 (1892).
[3] *Ibid.*, Vol. XXVIII, p. 55 (1895)

rapid decline in yield as the shallower sands. A small production was obtained from the Masimpur area, but the same water trouble was experienced in the 4 wells drilled. The Patharia area is being tested by a second well.

TABLE 88.—*Output of the Digboi oil refineries in the years 1924 to 1928.*

——	1924	1925	1926	1927	1928
Kerosene (*a*)	3,899,576	6,297,662	9,457,881	9,979,614	11,976,179
Batching and lubricating oil (*a*).	428,515	358,055	377,061	420,371	342,054
Spirit (*a*)	1,565,023	1,749,715	2,932,973	3,133,356	5,186,031
Wax and candles (*b*) . .	2,735,339	2,650,969	7,989,739	10,184,181	11,657,062
Sundry oils (*a*)	395,833	1,226,874	2,117,451	1,678,767	3,974,735

(*a*) Imperial gallons.
(*b*) lbs.

Burma.

The most productive oil-fields of Burma are those on the eastern side of the Arakan Yoma, forming a belt stretching along the valleys of the Chindwin and the lower half of the Irrawaddy, and including the oil-fields of the Upper Chindwin, Yenangyat in the Pakokku district, Singu in Myingyan, Yenangyaung in Magwe, and the Thayetmyo and Minbu fields. It has been shown that this belt coincides with the site of a gulf which existed in the Pegu epoch (approximately Oligocene and Miocene), and which gave place to a river, the forerunner of the present Chindwin-Irrawaddy[1]. The production of the Burmese oil-fields for the years 1924 to 1928 is shown in Table 89.

Yenangyaung.

Yenangyaung, the oldest and best known of the fields, maintained its lead as a producer during the quinquennial period, but there is little doubt that its place, during the next five years, will be taken by Singu. Of the total $1\frac{1}{2}$ square miles of petroliferous territory, all that outside the two 'Reserves' of Twingon and Beme is held under lease by the Burmah Oil Company, the pioneers of this field. It is within

[1] *Mem. Geol. Surv. Ind.*, Vol. XL, p. 251 (1920).

the two small reserved tracts, covering jointly some 450 acres, and especially within the Twingon Reserve, that competition has been so keen as to threaten injury to the oil-sands by water liberated from water-sands, and by fire in the midst of a congested forest of greasy wooden derricks covering highly productive flowing wells emitting immense quantities of inflammable gas. The appointment of a Warden, assisted by an Advisory Board composed of representatives of the companies engaged in exploiting the field and an officer of the Geological Survey of India, resulted in systematic measures for the protection of the sands, and has undoubtedly done much to prolong the life of the field.

TABLE 89.—*Production of the Burma oil-fields during the years 1924 to 1928.*

Oil-field or District.	1924	1925	1926	1927	1928	*Average.*
	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.
Akyab . .	7,014	7,169	6,331	5,627	5,260	*6,280*
Kyaukpyu .	14,708	14,361	15,103	15,452	15,227	*14,970*
Minbu . .	3,829,041	3,248,566	4 533,420	5,199,950	6,101,822	*4,582,560*
Singu . .	79,938,430	95,262,510	95,745.504	98,691.437	113,986,736	*96,924,925*
Thayetmyo .	1,717,653	1,320,009	974,620	999.500	727,322	*1,147,821*
Upper Chindwin	1,474,898	1,385,977	1,255,840	1,825,120	2,308,880	*1,650,113*
Yenangyat .	1.591.517	1,562,444	1,778,041	1,844,946	3,072,222	*1,970,431*
Yenangyaung .	181,636,739	160,027,885	115,731,612	137,322,012	135,969,794	*151,937,609*
TOTAL, Gallons .	**270,213,003**	**262,828,930**	**250,040,471**	**245,904,044**	**262,187,263**	*258,234,742*
Total, metric tons	*1.085,192*	*1,055,538*	*1,004,179*	*987,566*	*1,052,961*	*1,037,087*

The bulk of the oil is obtained from the deeper sands—at 3,000 feet and over,—but the first four years of the quinquennial period showed a steady decline from about 181 million gallons to $137\frac{1}{3}$ million gallons. By special effort the production, in 1928, was raised to nearly 140 million gallons, but it is manifest that without intensive drilling and pumping, the decline in this field must persist. The average annual output was some $29\frac{1}{4}$ million gallons short of that obtained during the previous five years. Wells tapping the deepest sands show a tendency towards a swifter decline in

yield; this is perhaps due to the natural shrinking and tightening of the anticlinal area, as deeper and deeper horizons are reached. The total depth to which the petroliferous horizons extend is still an unanswered question. The decline in production was mitigated to some extent by an organised exploitation of the shallower sands which had been largely shut off during the competitive rush for the richer deeper sands. The more important of the shallow horizons are those at 350 and 650 feet. The average daily yield from these shallow wells varies from $1\frac{1}{2}$ to 2 barrels each; in 1927, the production from the shallow wells amounted to nearly 14 per cent. of the total oil obtained from the field. It is curious to find oil still being won from the Burmese hand-dug wells; in each of the years 1924 and 1925, between 2 and $2\frac{1}{2}$ million gallons were obtained in this primitive fashion. A higher production is obtained from wells in the Burmah Oil Company's Kodaung tract lying between the two 'reserves'. This is due partly to the geological position of the block and to the more youthful stage of its producing life, but chiefly to the absence of competitive drilling. The number of producing wells in the Yenangyaung field at the end of the period amounted to nearly 2,450, including about 150 hand-dug wells. The electrification of the field which reached its limit of practicability in 1924, added an appreciable contribution to the production figure owing to the saving of a considerable quantity of crude oil formerly used as fuel beneath rig-boilers.

About 10 companies have been operating in this small field and of them the Burmah Oil Company produce about four-fifths of the total output. The northern part of the Yenangyaung field has been found to be richer than the southern. A test well put down in Block 2 S. is now the deepest well in Burma, having reached, in 1928, a depth of 5,267 feet; oil and gas sands are reported to have been struck below 5,000 feet, but trouble with the well prevented any estimation of the yield. There is now good reason to believe that as the depth increases, the crest of the Yenangyaung anticline recedes more and more to the east. The result of this is that the producing limits of oil pools are found further and further eastwards as greater depths are attained; deep test wells are being sunk to prove this. On the eastern flank of the anticline, an advance of 'edge' water has shown itself up one of the oil-sands. Fires and accidents are now an unfortunate feature of the field.

The relative merits of repressuring and suction are now exercising the minds of operators in Yenangyaung. It seems probable that both processes, employed at the proper time, will be found useful in increasing the yield from the various sands to which they are applied. To make full use of gas pressure in the oil-sands, it would appear advantageous to use the repressuring process as long as possible and to postpone the use of vacuum. The adverse effects of vacuum are not only the removal of the driving force in the form of gas, but an abstraction of the lighter compounds of the crude oil causing earlier paraffination of the sands. On the other hand, it is difficult to decide to what extent the result of repressuring is an actual increase in the total crude oil extracted from the sand, or is merely accelerated production.

Singu.

The place of Yenangyaung is being steadily taken by the Singu field which, in the next five years, will most probably usurp the premier position held so far by the older field. Singu, the greater part of which is in the hands of the Burmah Oil Company, is used to make good the deficiencies of Yenangyaung, in order to maintain supplies to the refinery. The production figures from Singu are, therefore, largely supplementary to those of Yenangyaung. This production has increased by uneven increments from nearly 80 million gallons in 1924, to nearly 114 million gallons in 1928. Many wells are producing from the second or 3,000-foot sand, the margin of which has been found to be inside that of the shallower sand in the southern end of the field, but outside it in the northern end. Initial yields of 500 barrels for 24 hours were frequent in the earlier years, but such a high figure is now seldom attained. Electrification was introduced into the field and the transmission line from Yenangyaung was completed in 1927. A number of wells are now being pumped and drilled by electric power; lighting has also been provided at the northern end of the field and power to the machine shops. The annual average production shows an increase of 2·5 per cent. in comparison with that of the preceding quinquennium.

Minbu.

The Minbu anticline is narrower and tighter than any of the three previously mentioned. The petroliferous area is therefore narrow and the yield from the wells diminishes somewhat rapidly. Much of the oil from this field is of a heavy type and less profitable to refine than

that produced from other fields. Minbu produced for the first time in the year 1910. In 1918, the production rose to 4·8 million gallons. During the 5 years which followed the annual production averaged under 4 million gallons. During the 5 years under review this field was more extensively exploited and the average annual output exceeded 4½ million gallons. A record figure amounting to over 6,100,000 gallons was obtained in 1928. Some 220 wells are producing in this area and deep tests are being sunk to explore its further possibilities.

Yenangyat.

The Yenangyat field which was never a rich one is rapidly dying; much of it is, in fact, already dead. Its production during the 5-year period under consideration has been little more than that from the Upper Chindwin field. Drilling was first started in 1891, by the Burmah Oil Company. The expansion was slow up to 1894, but rose rapidly to a yield of over 6 million gallons in 1898, and in 1903, the highest production recorded from this field was obtained, namely, 22,665,578 gallons. Subsequent to that year a decline set in, gradual at first, but severe after 1906. Between 1909 and 1918, production averaged a little over 5 million gallons. From 1918 onwards, the decline was gradual but persistent until 1925, when it had sunk to little more than 1½ million gallons. Since 1925, there has been a gradual recovery. In 1927, the output was 1,811,946 gallons. In 1928, the yield rose to 3,072,222 gallons—a stride due to increased drilling on the part of the Burmah Oil Company and also to expansion by the Indo-Burma Petroleum Company in the Lanywa area in the south. A scheme, by which the sand-bank stretching southwards from the wells of Lanywa into the river Irrawaddy is to be protected by a revetted enbankment, was started in 1927, and has enabled a number of wells to be drilled by the Indo-Burma Petroleum Company on the sand-bank. Strictly speaking, the area belongs tectonically to the Singu dome area, but for convenience of administration it is regarded officially as part of the Yenangyat field. The sand-bank which stretches from Lanywa to Sitpin is a more or less permanent feature, dry during the winter but covered by the floods of the rainy season. The striking of remunerative supplies of oil at Lanywa has made it almost certain that the river Irrawaddy covers oil deposits of commercial size. The question of reaching the sub-fluviatile deposits by means of a tunnel beneath the river large enough to accommodate drilling derricks is now under consideration.

With regard to the Thayetmyo fields, a proposal is under consideration by which the Yenanma and Padaukpin fields are to be further developed by sinking shafts and mining for oil. Drilling operations, commenced in 1924, by the Indo-Burma Petroleum Company on the Pyaye anticline, some 7 miles southwest of Thayetmyo, encountered nothing but gas and water. One well at a depth of 2,000 feet liberated gas in quantities estimated at 39 million cubic feet per 24 hours; the noise produced by its escape could be heard in Thayetmyo. With great difficulty and after 5 months of open flowing the well was got under control. This gas well was estimated to be thermally equivalent to an oil well of something like 5,000 barrels a day. In 1922, the Thayetmyo district yielded as much as 2,319,835 gallons but the average annual output for the quinquennium 1919-23 amounted only to 881,981 gallons. During the five years under review this average figure rose to 1,147,821 gallons.

Thayetmyo.

Tests are being continued in the Minhla area and indications of oil are not entirely wanting.

Minhla.

The Upper Chindwin field of Indaw, under the Indo-Burma Petroleum Company, began to produce in 1918, yielding nearly half-a-million gallons. The fact that after much laborious and expensive prospecting this is the only area in Burma additional to those described in 1912, in the Geological Survey Memoir, which has ever got beyond the testing stage, will dispell any illusion regarding Burma's present or future position amongst the world's producers of petroleum. Between 1919 and 1923, the Upper Chindwin field produced steadily over one million gallons a year, the average being 1,162,627 gallons. During the period under consideration, this average annual production rose to 1,650,143 gallons, with a record production in 1928, of 2,308,880 gallons.

Chindwin.

Besides the Upper Burma oilfields, the islands of the Arakan coast, noted for their mud volcanoes, have been known for many years to contain oil deposits of uncertain but probably indifferent value. Operations have been carried on principally in the Eastern Baronga island near Akyab, and on Ramri island in the Kyaukpyu district. Folding and denudation in these regions have been too severe to warrant the expectation of oil in much quantity. The output both from the Kyaukpyu wells and from those in the Akyab area showed a

Arakan Coast.

marked average decline during the 5 years, 1924 to 1928, as they did during the previous quinquennium.

Ruby, Sapphire and Spinel.

[J. COGGIN BROWN.]

Production.

With the exception of the sapphires from Kashmir, the whole of the Indian Empire's production of rubies, sapphires and spinels for the period under review was obtained from the Mogok Stone Tract of Upper Burma. The stones are won both by the Burma Ruby Mines Limited, and by a large number of indigenous workers who exploit various types of gem-bearing ground by primitive methods. No records are kept of the output of the latter industry and the statistics which have been given in earlier reviews, as well as those quoted herein, refer only to the production of the Company. Table 90 shows these annual output figures for the period 1924-28, the average annual value being only £26,228 as compared with £60,660 for the previous quinquennium. This reduction is not surprising, for the Company went into liquidation in 1925.

TABLE 90.—*Production of Rubies, Sapphires and Spinels by the Burma Ruby Mines, Ltd., during the period 1924 to 1928.*

Years.	Quantity.	Value.	
	Carats.	Rs.	£
1924	101,097	*4,83,710*	34,773(*a*)
1925	149,037	*3,65,139*	27,454(*b*)
1926	105,571	*4,66,772*	34,834(*c*)
1927	39,590	*2,79,834*	20,833(*c*)
1928	40,380	*1,77,512*	13,247(*c*)
Average	*87,135*	*3,54,519*	*26,228*

(*a*) £1 = Rs. 13·9. (*b*) £1 = Rs. 13·3. (*c*) £1 = Rs. 13·4.

The Burmese industry.

A race of hereditary gem miners exists in Mogok, and the methods of the old Burmese administration, modified in accordance with the principles of equity, form the foundation of the Upper Burma Ruby Regulation under which their activities are carried on. The interests of the native miner were fully safeguarded when a lease was given to the Burma Ruby Mines Ltd. Licenses to win gems are granted to descendants of the old families and land is allotted to them as occasion arises. The royalty received by the Local Government on account of license fees for the winning of rubies, sapphires, spinels, etc., is the only index we possess of the condition of the indigenous industry. Table 91 shows that an average annual royalty of Rs. 1,20,490 was received for the period under review.

TABLE 91.—*Royalty collected in Burma on Rubies, Sapphires and other Precious Stones.*

Year.	Amount.
	Rs.
1924	1,00,430
1925	1,07.896
1926	70,805
1927	1,03,040
1928	2,20,280
Average . .	*1,20,490*

The increased royalty collected in 1928, is gratifying and indicates a return, whether temporary or not is uncertain, to approximately the average annual amount realised during the more prosperous days of the industry at the beginning of the present century.

It is not generally realised that in addition to rubies, sapphires and spinels, gems which in their better classes are of incomparable beauty and as far as rubies and spinels are concerned, easily the finest specimens found anywhere in the world, Burma produces a further wide range of precious and semi-precious stones amongst which gem varieties of the following minerals are of frequent occurrence :—

Quartz (Amethyst, etc.), Apatite, Beryl (Aquamarine), Chrysoberyl, Epidote, Garnet, Iolite (Water Sapphire), Lapis Lazuli,

Felspar (Moonstone), Olivine (Peridot), Phenakite, Tourmaline (Rubellite), Topaz, Zircon (Hyacinth).

Kashmir.

In 1926, 1·6 cwts. of corundum with patches of sapphire are said to have been obtained; in 1927, 11 cwts. and in 1928, 1 cwt. of the same rock figure in the returns.

Burma, History.

The original Mogok Stone Tract was annexed by the ruling Burmese monarch in 1597, but precious stones had probably been obtained therein for long periods before that date. This is not the place to trace the history of the tract in detail and it must suffice to state that Mogok was occupied by the British in 1886. In October, 1887, the Upper Burma Ruby Regulations (XII of 1887), a regulation to declare the law relating to rubies and other precious stones, came into force and by it the Local Government were empowered to notify the 'stone tracts' and to make rules regarding the mining, cutting, possession, buying, selling and carrying of precious stones and to grant licenses for these purposes. In November, 1887, the Mogok Stone Tract was constituted. It is contained within the boundaries of the existing Mogok township, which enclosed the older Burmese townships of Mogok, Kyatpyin and Kathe.

The first lease of the Burma Ruby Mines Limited, was granted in 1889, a second one came into operation in 1897, and a third one for a period of 25 years in 1904. It was about 1907, that the market for gem stones became depressed and subsequent events were ably summarised by Sir Edwin Pascoe in the Quinquennial Review for 1919-1923. It is only necessary to add here that in 1925, the company went into voluntary liquidation and such stones as have been won since that date, are due in part to its letting out certain gem-bearing areas on a modified tribute system. The regrettable demise of this famous concern after its chequered career of 36 years is best quoted in the words of the 'Note on the Mineral Production of Burma during the year 1925.'

'The Sinkwa mine was closed during the year. The best parts of the Mogok and Kathe valleys are reported to be approaching exhaustion and the residue of ruby-bearing ground in these areas is said to be insufficiently rich to pay for extensive working. These mines are now let out to tributors who clean up patches of ruby-earth left in crevices and detached spots. The loss on last year's

working has finally exhausted the capital of the company which has since decided to go into voluntary liquidation.'

In the opinion of the present writer, who has devoted some time to the study of the industry, the present condition of gem-mining in Burma is due to the cumulative effect of numerous adverse causes, but exhaustion of the gem-bearing deposits as a whole is not one of them. The Mogok Stone Tract occupies more than 600 square miles, the greater part of which is occupied by gneisses and associated rocks of Archaean age, amongst them being great bands of crystalline limestone from which most of the precious and semi-precious stones, and all the rubies and spinels, have been derived. The weathered products of the limestone have accumulated in the water-borne gravels and it follows of necessity from the existence of gems in such situations, that they occur also in the detrital deposits of the hill slopes, whence the true alluvials are derived. The operations of the Burma Ruby Mines Limited, apart from early abortive attempts to mine gems from solid limestone and a few inconclusive experiments on certain hill slopes, were mainly confined to the removal and treatment of gravel from the Mogok, Kyatpyin and Kathe valleys. There are other valleys in the stone tract, in which gems are known to occur, and which deserve fuller exploration than they have hitherto received, with the object of proving their value as hydraulicing propositions, rather than as deposits to be opened up by costly and laborious hand methods.

Rubies and other precious stones are known to occur at other places in Burma and 'stone tracts' have been declared by the Local Government to exist within certain areas in the state of Mongmit and its dependency Mong Lang; within the Thabeitkyin township of the Katha district; within the Myitkyina district (the Nanyaseik Stone Tract); within the Mandalay district (the Sagyin Stone Tract) and within the state of Kengtung.

Salt.

[W. A. K. CHRISTIE.]

General.

The average annual production of salt in India during the five years 1924 to 1928 was 1,343,587 statute tons (*see* Table 92). The corresponding figure for the previous quinquennium was 1,530,272 so there was a drop in production of 186,685 tons per annum. Imports, on the other

hand, increased from an annual average of 517,894 tons in 1919-1923, to 580,943 tons in 1924-1928, an increase of 63,049 tons a year. The salt produced in the country *plus* that imported by sea has fallen from about 2,050,000 to about 1,920,000 tons a year. From these figures we can get a rough idea of the consumption per head. Taking the census figures for 1921 and even assuming no increase in population for the later quinquennial period we find that the consumption per head has fallen 6 per cent., from 14·4 lbs. to 13·5 lbs., which is about the pre-war figure. This figure includes manufactured salt used in animal husbandry and in industry (chiefly fish curing), so the amount eaten per inhabitant will be somewhat less. 14·3 lbs. per head per annum is the figure usually adopted as sufficing;[1] the consumption, then, is nearly normal for physiological requirements.

Salt Duty.

The salt duty goes to central and not provincial revenues and is now collected by the Central Board of Revenue. At the beginning of 1924, it stood at Rs. 2-8 per maund of $82\frac{2}{7}$ lbs., having been raised in the previous year from Rs. 1-4. On 1st March, 1924, it was reduced again to Rs. 1-4 per maund (Rs. 34 per ton) and was maintained at that rate during the remainder of the five years under review. There was a sharp drop in imports of salt during the year, 1923-24, of the enhanced duty; the imports in 1922-23 were 542,000 tons, in 1923-24 475,000 tons, in 1925-26 616,000 tons. The influence of the change in the rate of duty is not so noticeable in the figures for the salt made in India. The abnormally low production in 1925, was largely due to restriction of production in Bombay, as large stocks were being carried while the duty was high, but unfavourable weather in Madras and Rajputana also contributed.

TABLE 92.—*Production of Salt in India (excluding Aden).*

Year.	Statute.	Metric.
	Tons	Tons.
1924	1,444,293	1,467,401·7
1925	1,106,651	1,124,357·4
1926	1,444,225	1,467,332·6
1927	1,430,188	1,453,071·0
1928	1,292,578	1,313,259·2
Average	*1,343,587*	*1,365,084·4*

[1] *J. von Buschman. Das Salz,* I, V.

Compared with the previous five years salt production has fallen 12 per cent. from a yearly average of 1,530,000 to one of 1,344,000 tons.

Sources of Indian salt.

The salt produced in India is obtained from three principal sources, (*a*) sea water, (*b*) lakes and subsoil water in areas where the rivers have no outlet to the sea, and (*c*) rock salt beds. Omitting the Aden production, about two-thirds of the salt made in India is recovered from sea water, chiefly in Bombay and Madras; about one-eighth is mined or quarried as rock salt, chiefly in the Punjab Salt Range; and the rest comes from areas of internal drainage, the Sambhar lake in Rajputana being the largest producer in this class.

Table 93.—*Provincial production of Salt.*

Province.	1924	1925	1926	1927	1928	Average.
	Statute Tons.	Statute Tons.	Statute Tons.	Statute Tons.	Statute Tons.	Statute Tons.
Aden	179,182	188,493	194,524	181,757	222,771	193,345
Bombay and Sind . .	538,777	381,419	473,127	432,993	460,873	457,438
Burma.	20,557	22,880	24,409	19,913	21,322	21,816
Gwalior (*a*)	151	141	176	435	60	193
Madras	407,544	336,605	481,826	543,081	448,538	443,519
Northern India . . .	477,264	365,606	464,686	433,765	361,783	420,621
Total Statute Tons . .	1,623,475	1,295,144	1,638,748	1,611,944	1,515,347	1,536,932

(*a*) Figures relate to official years.

Again excluding Aden, we find that the total reduction already noted is distributed over all the large producing areas. Bombay's average production has fallen 15 per cent. compared with that of the previous five years, that of Madras 8 per cent., and that of Northern India 9 per cent. (The expression Northern India embraces the salt lakes of Rajputana and the rock salt areas of the Salt Range and Kohat.)

Bombay salt.

Bombay, in spite of a 15 per cent. reduction in output, is still the largest producer. Most of the salt is made by the direct solar evaporation of sea water. The factories at Dharasna and Chharvada on the eastern side

of the Gulf of Cambay near Bulsar are both Government property and worked departmentally. The other sea salt works, with three exceptions, are grouped within a radius of 30 miles of Bombay City. Those which are Government property are leased to private individuals for working; the others are owned as well as worked privately. A site for a salt works is usually chosen below the level of high water spring tides and surrounded by a strong embankment. Within this are situated the outer and inner reservoirs and the pan area. The outer reservoir is filled when the tide is high; from it the brine flows to the inner reservoir, where it is concentrated until the calcium carbonate and calcium sulphate have been deposited; the brine, then nearly saturated with salt, is run, to a depth of about one and a half inches, into the crystallising pans, generally about 18 feet long and 10 feet broad, whose floors have been levelled and tamped with clay. After a few days, when a layer of salt crystals about a quarter of an inch thick has formed on the bed of a pan, the salt is raked to the edges of the pan, washed with the mother liquor, allowed to dry, sieved into various sizes to suit different markets and stored in conical heaps. The pan is replenished with concentrated brine for another crop. The season of manufacture varies with the South-west monsoon, January to June being the normal period. A considerable proportion of the Bombay salt production is Baragra or Rann salt, made from brine wells on the Little Rann of Cutch. There are salt works at Kharagoda and at Udu, owned by Government and worked departmentally. Since 1923-24 Dhrangadhra State has been permitted to make this kind of salt at Kuda and Government agreed to buy 18,000 tons annually for five years from that time. The largest works on the Rann is at Kharagoda. There the brine is obtained from circular wells about 9 feet in diameter and 18 to 30 feet deep. The brine is lifted in earthenware pots on weighted levers and discharged into a reservoir. After concentration there it is led into pans about 250 feet long and 60 feet wide. In about a week the layer of salt crystals on the floor of a pan is broken up by treading and raking, and more brine is admitted. Every second day the salt is raked over, and the level of the brine is kept at least three inches above the top of the salt. After about five months the crop, about 180 tons to a pan, is collected. The manufacturing season lasts from November to April. A large quantity of salt is made in Sind at the Maurypur salt works on the sea coast about eight miles west of Karachi.

There, too, the brine is lifted from wells, large numbers of which are sunk beside the salt pans. Many thousands of yards of trenches have been dug round and across the works; these are filled with sea water at spring tide once a fortnight. The trenches not only act as condensers for concentrating purposes, but also, by keeping up the hydraulic head, increase the flow of brine in the wells. The salt crystals are scraped from the pans after a single irrigation and the pans are then replenished for another crop. By using crystallising pans of cement or tiles instead of clay--the usual material- a private company is now producing salt of superior quality, rivalling that from Aden or the Mediterranean. Considerable quantities, both in the natural state and crushed, have been shipped to Calcutta to compete with salt imported from abroad. Of the areas producing salt in India, Karachi is probably the most favourably situated. The mean annual rainfall is only 7·64 inches, normally distributed over 9 days; generally the air is comparatively dry and seldom still; the mean daily maximum temperature is 84°F.; so conditions and opportunities for making salt when the sun shines are excellent, and manufacture goes on for about eleven months in the year. Dr. J. A. Dunn[1] has written an interesting account of the Maurypur salt works. He considers the area a promising one for an extension of manufacturing operations up to 200,000 tons per annum.

Madras salt.

In the Madras Presidency all the salt is made from sea water in much the same way as at Bombay. The brine is usually brought from tidal backwaters through channels, from which it is baled into condensing beds. When it has reached a density of 25° Baumé, it is run into the crystallising pans, whose floors have been levelled and well rammed. After three or four days the salt formed is scraped on to the ridges of the pans, washed with the mother liquor, allowed to dry, and then stored on platforms in heaps until it is sold. After a crop of salt has been removed, the pans are again charged with brine and the process is repeated. After every fifth scraping the mother liquor is removed--to prevent contamination of the salt with salts of magnesium which have then reached a dangerous concentration--and the pans are retamped. In some factories the pans are irrigated several times before the layer of salt crystals is removed, but the 'single

[1] *Rec. Geol. Surv. Ind.*, Vol. LVI, p. 385 (1925).

irrigation' system is the common one. The season of manufacture varies according as the factory is subject to the South-west or North-east monsoon. In the northern districts manufacture commences in January or February and continues till June or July, when the rains begin. Further south, manufacture commences later, in March or April, and continues up to August or September. In some of the southernmost factories, like Tuticorin, manufacture continues up to October and even November. There are three systems of control in the Presidency—'monopoly', 'excise', and 'modified excise'. Under the 'monopoly' system the licensees manufacture salt of a prescribed standard and sell it to Government at a fixed rate. Licensees under the 'excise' system are allowed to manufacture and sell salt as they like, under certain conditions, the chief being that the salt made must not contain more than five per cent. of magnesium salts or more than five per cent. of dirt. Under the 'modified excise' system the licensee ordinarily manufactures salt for his own sale, but he may be required at any time before the commencement of the season to sell a portion of his salt to Government at a fixed price. Private enterprise in salt manufacture can thus be encouraged and Government can, if necessary, regulate the price of salt.

Madras salt is mainly consumed in the Presidency itself and the Indian States contiguous to it. About 15,000 tons are exported annually to Ceylon. After a lapse of several years, Madras salt (from Tuticorin) is again being shipped to Calcutta.

Burma salt.

Only a quarter of the salt consumed in Burma is made there; the rest comes from abroad. Most of the annual production of about 22,000 tons is made from sea water in the districts of Akyab, Kyaukpyu, Sandoway, Hanthawaddy, Bassein, Myaungmya, Thaton, Amherst, Tavoy and Mergui. The method used differs widely from that used in India. The sea water is passed through a series of condensers until the calcium sulphate has been precipitated as anhydrite. The concentrated brine, about 25° Baumé, is fed into large iron cauldrons, and evaporated over a fire. The salt is scraped out as it forms and thrown through a wooden grating into a drying chamber. The Burmese insist on having a fine white salt such as is thus produced. Efforts to introduce the system of solar manufacture used in India—which normally yields a coarse salt of inferior colour—have not met with success.

In Upper Burma, in the districts of Magwe, Pakokku, Myingyan, Yamethin, Shwebo, Sagaing, Katha, Meiktila, Upper Chindwin and Lower Chindwin, salt is made in hundreds of small works, either from brine wells or by lixiviating saline soil. Salt is always recovered by boiling the solution. A careful description of the method of making salt from well brine at Bawgyo, in the northern Shan States has been given by T. H. D. La Touche.[1] Of the total salts in solution 36 per cent. was sodium sulphate.

Sub-soil and lake-brine.

The most important of the areas worked for sub-soil and lake brine is the desert region of Rajputana. The whole country is impregnated with salt from the coast of Cutch and Sind north and north-eastwards to the borders of Delhi district and Bahawalpur State. In many areas of internal drainage there are temporary salt-lakes, which are utilised, as at Sambhar and Didwana; while in other places sub-soil brine is raised, as at Pachbadra. Most of the salt in this region appears to be brought in as fine dust by the strong winds which blow from the south-west and south-south-west during the hot weather. These winds blow across the salt-incrusted Rann of Cutch, and carry away sea-spray and finely-powdered salt in large quantities into the heart of Rajputana, where it becomes fixed when the following monsoon brings rain enough to wash the salt into the small lakes in areas of internal drainage.[2]

Sambhar Lake.

Sambhar, the largest of the Rajputana salt-lakes, covers an area of about 90 square miles at its highest level, but dwindles, generally, to a small central puddle by March or April. It has been shown by careful sampling at regular intervals that the mud forming the bed of the lake contains on an average 5·21 per cent. of sodium chloride down to a depth of at least 12 feet, and the amount stored in these higher layers of salt cannot thus be less than fifty million tons. When the lake dries up brine contained in its clay bed rises to the surface by capillarity and is there evaporated to dryness. By a continuation of this process there is produced each year on the top of the lake bed a layer of salt ready for rapid solution by the monsoon rains.

Against floods Sambhar cannot be protected, but against a scarcity of rain protection is now good. Due chiefly to measures

[1] *Rec. Geol. Surv. Ind.*, Vol. XXXV, p. 97 (1907).

[2] T. H. Holland and W. A. K. Christie; *Ibid*, XXXVIII, pp. 154-186 (1909).

devised by Mr. S. A. Bunting,[1] it is now possible, even in a season of scanty rainfall, to collect enough brine for the season's manufacture before the lake recedes too far from the shores. A substantial dam has been built across the lake near the Sambhar end, and into a reservoir of about five square miles brine from the main body of the lake can be transferred by powerful pumps at the dam. After concentration in this reservoir it is transferred to smaller condenser-reservoirs and then to groups of evaporating pans called *kyars*. A large new *kyar* of eight million square feet, built on improved lines, was brought into operation during the period under review. It took some time to 'find itself', but it is now functioning satisfactorily and yielding a superior quality of salt. More complete arrangements have been made for isolating the mother liquors after the salt crop has been extracted. The transport system, too, has been reorganised and salt on extraction is now railed direct to a large central store at Sambhar with considerable saving of labour.

Table 94 shows the average annual distribution of Sambhar salt during the five years 1923-24 to 1927-28 with the corresponding figures for the previous quinquennium. The increase in production was again absorbed by the United Provinces. Sambhar salt seems to have reached its limit of economic transportation in Bihar.

Pachpadra. The production at Pachpadra has again declined and the average annual despatch of salt is now only 16,000 tons.

TABLE 94.—*Average annual distribution of Sambhar Salt.*

—	1918-19 to 1922-23		1923-24 to 1927-28	
	Quantity.	*Per cent. of total.*	Quantity.	*Per cent. of total.*
	Tons.		Tons.	
United Provinces	157,574	*68·4*	178,419	*72·1*
Rajputana	28,044	*12·2*	28,566	*11·5*
Central India	15,471	*6·7*	19,595	*7·9*
Punjab including Feudatory States and Delhi.	8,640	*3·7*	11,397	*4·6*
Central Provinces	4,081	*1·8*	5,662	*2·3*
Bihar and Orissa	16,338	*7·1*	3,971	*1·6*
Bengal	118	*0·1*	..	..
Bombay	74	*0·0*	..	..
Average Total	*230,340*	*100·0*	*247,610*	*100·0*

[1] Inst. Civil Engineers. Selected Engineering Papers. No. 30. 1925.

Rock-salt. The production of rock salt has fallen about 9 per cent. Details are shown in Table 95.

TABLE 95.—*Production of Rock-salt during the period 1924-28 compared with the period 1919-23.*

Year.	Salt Range, Punjab.	Kohat, North-West Frontier.	Mandi State.	Total.	*Percentage of total salt production of India.*
	Tons.	Tons.	Tons.	Tons.	
1924	160,049	24,485	4,703	**189,237**	*11·7*
1925	125,470	19,971	4,939	**150,380**	*11·6*
1926	122,895	19,224	4,552	**146,671**	*8·9*
1927	145,750	21,161	3,837	**170,748**	*10·6*
1928	131,730	19,812	3,811	**155,353**	*10·2*
Average for 1924-28 . .	*137,179*	*20,931*	*4,368*	*162,478*	*10·6*
Percent of average total 1924-28.	*84·4*	*12·9*	*2·7*	..	..
Average for 1919-23 . .	*152,725*	*20,451*	*4,862*	*178,038*	*10·5*
Percent of average total 1919-23.	*85·8*	*11·5*	*2·7*	..	..

A general account of the occurrences of rock-salt in the Punjab and North-West Frontier Province will be found in a previous Review (Records, Vol. XXXII, pages 83, 84) and in a paper by the writer published in the Records (Vol. XLIV, pages 241-264). The mines of the Salt Range are responsible for by far the largest share of the output. A very good description of the salt mines and the methods of excavation employed has been given by Mr. C. H. Pitt,[1] the General Manager. The Mayo mine at Khewra, much the largest in the Range, is worked in a series of alternate chambers and pillars running parallel to the dip of the salt seams, the pillars increasing in thickness from 25 feet at the top to 35 feet at the bottom while the width of the chambers decreases correspondingly from 45 feet to 35. There are now about 40 working chambers. Some of the older chambers are very large—700 feet long and 200 feet high—but the mine shows no signs of instability. Mr. Pitt estimates that, with the present system of working and rate of production,

[1] *Trans. Min. Geol. Inst. India,* Vol. XXII, p. 197, (1928).

the mine has reserves for at least 50 years. During the last five years mechanisation of haulage and excavation has proceeded apace and an electrification scheme has recently been completed. For drilling and cutting, air compressors in the mine are now direct coupled to 300 H.P. motors taking alternating current at 3,000 volts from the power station. For other purposes the current is transformed down to 400 volts. At the Warcha mine, which is a replica of the one at Khewra on a small scale, mechanical methods have also been introduced. Here the presence of faults is likely to curb extension. Prospecting in the Jansukh valley, however, about one and a half miles north-east of the mine, has given promising results. Mr. E. R. Gee of the Geological Survey considers that a very thick seam of workable salt exists in the area.

Gypsum in the Salt Range.

At Khewra the quarrying of gypsum has been started as a subsidiary industry and about 2,000 tons were sold in the year 1927-28 by the Department of Northern India Salt Revenue.

The excavation of potash salts, to which reference was made in the last Review, has been discontinued.

Imports of salt.

Imports from foreign countries continue to increase, and the figure representing the annual average for the five years is a record one—12 per cent. higher than the average for the previous five years.

TABLE 96.—*Average annual imports of Salt during 1919 to 1923 and during 1924 to 1928.*

—	1919 to 1923		1924 to 1928	
	Quantity.	*Per cent. of total.*	Quantity.	*Per cent. of total.*
	Tons.		Tons.	
United Kingdom	88,468	*17·1*	82,656	*14·2*
Germany	44,043	*8·5*	47,698	*8·2*
Spain	55,079	*10·6*	52,106	*9·0*
Aden and Dependencies	160,905	*31·1*	193,850	*33·4*
Egypt	111,447	*21·5*	130,205	*22·4*
Italian East Africa	56,984	*11·0*	54,246	*9·3*
Other countries	968	*0·2*	20,182	*3·5*
Average annual total	**517,894**	***100·0***	**580,943**	***100·0***

Aden is largely responsible for the increase of 63,000 tons and it again furnishes the largest individual import figure. Aden has an ideal climate for making salt, with a negligible rainfall, a low humidity, comparatively high temperatures all the year round, and warm winds, which are effective drying agents, for ten months in the year. Add to these advantages the flatness and low level of the plain at Sheikh Othman; its easily worked, although impermeable, clayey soil; the low ballast freights in ships that have discharged coal; and one need not wonder at the strides which Aden salt is making in capturing the markets served from Calcutta. Sea salt is also imported from various ports on the African littoral of the Red Sea--the imports under 'other countries' in Table 96 are largely from French Somaliland, from Port Said, from several ports in Spain and from Tunis. Brine salt, from Liverpool and from Hamburg, commands the highest prices. Rock salt, both lump and crushed, comes mainly from Germany, but a considerable quantity has recently been imported from Roumania. A shipment of lump rock salt from Liverpool was received in 1926, but the experiment has not been repeated.

Of the imports from foreign countries, Bengal ports claim 85 per cent.; the remainder goes mostly to Burma.

Indian imports to Bengal.

Salt is also imported to Bengal from other parts of India. Madras, after having been out of the market for several years is again shipping salt from Tuticorin to Calcutta. From the Bombay Presidency, salt is now coming in from the new port of Okha in the part of Baroda State at the mouth of the Gulf of Cutch. Some of the salt imported from Bombay has the colour of brown mud, but commands a price out of all proportion to its quality. Therapeutic qualities are apparently attributed to this variety, and it finds a ready sale in the Nadia and Burdwan districts of Bengal. Karachi salt, both natural (*Karkach*) and crushed, much of it of a better quality than the usual Indian sea salt, is establishing a footing in Calcutta. As far as the crushed variety is concerned, it is disposed of easily enough in competition with foreign, crushed, sea salt; the difficulty of the importers is that there is not enough of it to satisfy market demands.

The question of the manufacture of salt on the coasts of Bengal has again been under discussion. Dr. R. L. Datta,[1] who investi-

[1] Govt. of Bengal, Industries Dept. *Bull.* 26, p. 5, (1927).

gated the rainfall and humidity statistics, confirms previous findings 'that there are no prospects for the salt-raising industry round the coast of Bengal'.

Saltpetre.

(E. H. PASCOE.)

Formation. The conditions necessary for the natural formation of potassium nitrate in a soil are :—

(i) a supply of nitrogenous organic matter,
(ii) the presence of potash,
(iii) climatic conditions favourable to the growth and action of nitrifying bacteria,
(iv) meteorological conditions suitable for the efflorescence of the salt at or near the surface.

An ideal combination of these necessary circumstances has made the Bihar section of the Gangetic plain famous for its production of saltpetre. In this part of India we have a population of over 600 per square mile mainly engaged in farming and agriculture, and thus accompanied by a high proportion of domestic animals supplying an abundance of organic nitrogen. The requisite potash is derived from the staple fuel, which consists very largely of cow-dung and wood. With a mean temperature of 78°F. during a large part of the year, and a comparatively high humidity combined with a low diurnal range in temperature, conditions in the Bihar plain are unusually favourable for the growth of nitrifying micro-organisms. The soil around villages would naturally be well-stocked with potash, and with a period of continuous surface desiccation following a small rain-fall, the sub-soil water, brought to the surface by capillary action in the soil, leaves an efflorescence of salts of which potassium nitrate forms a conspicuous proportion. Similar conditions obtain in parts of Egypt. The saltpetre industry has flourished for centuries in India, and received a marked impetus during the days of the American Civil War, when the salt was an essential ingredient of all explosives and when India practically held a monopoly of its production.[1]

The houses of Indian villages consist for the most part of mud and, as a consequence, frequently tumble down and have to be

[1] P. C. Tallents; Census of India, 1921, Vol. VII, pt. I, p. 25.

renewed. The village site thus becomes gradually raised, and as the floors of the houses are frequently made of mud and cow-dung, there is built up a nitrogenous deposit, which is reinforced by other forms of animal refuse and to which are added the wood ashes of innumerable fires. The decaying refuse undergoes nitrification, and the product drains from these raised village sites into lower levels and separates out as an efflorescence consisting largely of sodium chloride, sodium sulphate and nitrates of potash and magnesium. The accumulations in some of the old village sites are the results of hundreds of years.

Manufacture.

The earths from which the crude saltpetre is extracted contain sometimes as much as 29 per cent., sometimes as little as 1 per cent., but not often more than 5 per cent. of nitrate. The process of extraction is described by C. M. Hutchinson.[1] Wood ashes are added to decompose any calcium nitrate in the earth, and the approximate proportions of the various salts in the drainage liquor are:—

	Per cent.
Sodium chloride	15·25
Potassium nitrate	7·24
Potassium chloride	0·40
Magnesium chloride	0·20
Calcium chloride	0·10
Calcium sulphate	0·10
Magnesium sulphate	0·10

On evaporation sodium chloride first crystallises out, and the nitrate is obtained later; the sodium chloride is consumed locally. The crude saltpetre varies greatly in composition, and always contains a considerable amount of sodium chloride. The following are analyses of high and low grade crude saltpetre:—

	High grade. Per cent.	Low grade. Per cent.
Potassium nitrate	66·07	26·86
Magnesium nitrate	2·54	12·24
Sodium chloride	21·84	34·80
Sodium sulphate	3·65	11·20
Insoluble matter	0·90	1·40
Water	5·00	13·50

[1] *Agri. Res. Inst. Pusa. Bull.* No. 68 (1917).

Some of this crude saltpetre (*kuthea*), which may contain from 30 to 50 per cent. of foreign matter, is used as a fertiliser but most of it is sent to refineries for the manufacture of gun-powder. The crude earths (*lona mati*), from which this saltpetre is extracted by lixiviation, are also used on the spot for manure purposes in north-western India, especially in the upper Doab where the people are well-to-do, and in parts of Bihar. According to Mukerji[1] it has been found more satisfactory to use nitrate manure in a comparatively pure form. The typical conditions for the formation of nitrate in the Bihar plain are repeated in the Punjab and the United Provinces. These two areas are, in fact, reported to turn out almost as much as Bihar.

Production.

Owing to the withdrawal of restrictions on the manufacture of saline substances in India, production figures for saltpetre subsequent to 1924, are no longer available. Production during 1924, was as follows:—

	Quantity.	*Value.*
	Tons.	*Rs.*
Bihar (refined)	1,820	*5,10,469*
Bihar (*kuthea*)	1,384	*2,98,944*
Central India	14	*2,951*
Punjab	3,315	*11,45,811*
Rajputana	24	*7,020*
United Provinces	1,829	*5,25,497*
Bengal	44	*10,791*[3]
Madras [2]	112	*32,554*[3]
TOTAL	8,542	*25,34,037*

Exports.

The returns for production do not always give a true index of the extent of manufacture; the figure for 1920, for instance, showed an excess of exports over production not explainable by invoking accumulated stocks. There was a heavy and continuous falling off in production during the preceding quinquennium, and the figure for 1924 would appear to be the lowest for at least 80 years. All the producing provinces

[1] N. G. Mukerji.—'Indian Agriculture' (1901).

[2] Production for the official years 1923-24 and 1924-25.

[3] Estimated.

shared in this reduction. The average yearly export for the five years was 6,061 tons, compared with 14,271 tons during the period 1919-23; during the War years 1914-18, when explosives' manufacture gave a stimulus to production, the average yearly export amounted to 21,737 tons. During the pre-War quinquennium 1909-13, export (16,576 tons) was in excess of that for any post-War year, so that the industry, on the whole, shows a general decline. For fertilising purposes, Indian saltpetre finds a serious competitor in an equivalent mixture of Chilian nitrate and French potash salts, but a certain amount is used on tea gardens.

The geographical distribution of exports since the War shows one or two notable changes. The United States, who for many years before the War were India's largest buyer of saltpetre, have now dropped completely out of the returns. During the three years, 1919, 1920 and 1921, the United Kingdom was the largest importer, but she has since been ousted by Ceylon, who now absorbs nearly three-quarters of the exports. Most of the saltpetre exported leaves India through Calcutta, the rest passing through Karachi, Bombay and, to a very small extent, Madras.

Provincial shares in the exports.

Calcutta is still, as it always has been, the chief port through which saltpetre leaves India, the exports during the period under review having amounted to 94·9 per cent. of the total, as compared with 88·4 per cent. during the preceding period. Bombay's and Karachi's shares of Indian exports during the period under review amounted respectively to 4·1 per cent. and 1·0 per cent. as against 2·3 and 9·3 per cent. during the preceding quinquennium. The average annual exports from the different provinces during the period 1924-25 to 1928-29 have been :—

	Tons.
Bengal	5,566·8
Bombay	239·9
Sind	55·5
TOTAL	5,862·2

TABLE 97.—*Distribution of Saltpetre exported during the years 1924 to 1928.*

	1924			1925			1926		
	Quantity.	*Value.*	*Per cent. of total quantity.*	Quantity.	*Value.*	*Per cent. of total quantity.*	Quantity.	*Value.*	*Per cent. of total quantity.*
	Tons.	*Rs.*		Tons.	*Rs.*		Tons.	*Rs.*	
United Kingdom	799·4	*2,30,014*	*9·5*	848·1	*2,36,172*	*13.4*	751·9	*1,50,044*	*15.2*
Ceylon	3,425·9	*8,62,089*	*40 9*	3,548·9	*8,76,326*	*55·9*	3,096·5	*7,16,452*	*62·7*
Straits Settlements (including Labuan).	239·7	*1,08,192*	*2·9*	232·6	*90,743*	*3.7*	278·3	*96,533*	*5.6*
Hongkong	1,779·9	*7,97,507*	*21 2*	1,067·8	*4,72,040*	*16.8*	564·1	*2,39,440*	*11·4*
Mauritius and Dependencies	1.809·7	*6,49,088*	*21 6*	441·4	*1,72 724*	*7.0*	97·3	*31,598*	*2.0*
Other countries	330·4	*1,52,323*	*3.9*	209·8	*1,15,296*	*3.3*	153·4	*60,173*	*3.1*
TOTAL	**8,385·0**	*27,99,213*	*100·0*	**6,348·6**	*19,63,301*	*100 0*	**4,941·5**	*13,24,540*	*100·0*
Total value in Sterling	..	*£201.382* £1 = Rs. 13·9	..	..	*£147,617* £1 = Rs. 13 3	..	..	*£98,846* £1 = Rs. 13·4	..

	1927			1928			Average.		
	Quantity.	*Value.*	*Per cent. of total quantity.*	Quantity.	*Value.*	*Per cent. of total quantity.*	Quantity.	*Value.*	*Per cent. of total quantity.*
	Tons.	*Rs.*		Tons.	*Rs.*		Tons.	*Rs.*	
United Kingdom	666·0	*1,54,074*	*10·8*	811·2	*1,95,348*	*18 1*	775 3	*1,99,130*	*13·4*
Ceylon	4,320·5	*9.42.667*	*70.2*	3,131·5	*6,04.892*	*69 9*	3,504·7	*8,00,485*	*59·3*
Straits Settlements (including Labuan).	192·8	*57,548*	*3.1*	143·4	*44,427*	*3·2*	217·3	*79,549*	*3·7*
Hongkong	102·5	*92,300*	*1·7*	..	..	..	702·9	*3,20,257*	*10.2*
Mauritius and Dependencies	693·5	*2.12,907*	*11·3*	304 2	*1,14,680*	*6·8*	669·2	*2,36,199*	*9.8*
Other countries	175·6	*63,170*	*2·9*	88·2	*40.687*	*2 0*	191·5	*86,330*	*3.0*
TOTAL	**6,150·9**	*15.22.666*	*100·0*	4,478·5	*10.00.034*	*100·0*	**6,060·9**	*17,21,950*	*100·0*
Total value in Sterling	..	*£113,632* £1 = Rs. 13·4	..	..	*£74.629* £1 = Rs. 13·4	..	..	*127,221*	..

Consumption in India.

A certain amount of saltpetre is used for agricultural purposes on the tea gardens of India. During the War when it was impossible to obtain supplies of imported potash the amount of locally produced nitrate utilised in this way reached an appreciable figure. The total quantity consumed during the quinquennium 1919-23 was in the neighbourhood of 4,000 tons. The practice continued and the quantities estimated to have been absorbed for fertilising purposes on tea gardens in 1924, 1925, 1926, 1927 and 1928, were 1,100, 800, 700, 500 and 250 tons, respectively. The gradual decrease since the year 1925, is due to the fact that it is found cheaper to employ a mixture of imported sulphate of ammonia and chloride of potash.

Trans-frontier imports.

Only very small quantities of saltpetre for chemical and medicinal purposes are imported into India by sea, but a considerable quantity comes from Nepal. During the five years 1919-20 to 1923-24, the imports from Nepal averaged 3,984 cwts. annually. Owing to the discontinuance of the old system of registration of trade by land and the introduction of a new system of registration from the 1st April, 1925, of selected commodities only and at certain selected railway stations adjacent to important land frontier routes, figures for the imports of saltpetre from Nepal are no longer available.

Burma.

Saltpetre is made on a small scale by the Kachins of the Northern Shan States. The soil is lixiviated with water by being packed into V-bottomed rectangular troughs some 5 feet long, 3 feet broad and 5 feet high, constructed entirely of bamboo. The trough is lined with the sheaths of bamboo stems laid like slates. The base of the trough consists of a very large split bamboo with perforations through which the liquor drips into another split bamboo and is by it led into a bamboo bucket. The liquor is evaporated on the spot in shallow iron pans similar to those used for the preparation of molasses. The saltpetre is all of it absorbed locally for the manufacture of gunpowder.

Earth containing about 6 per cent. of saltpetre has been noted in the compounds of *hpongyi kyaungs* and around the bazar at Pyindaw in the Yamethin district of Burma, but nothing is known as to the quantity present.

Silver.

[G. VERNON HOBSON.]

There are no known occurrences of silver ores mined primarily as ores of silver, in India, the metal being obtained entirely as a by-product in the mining of gold and lead. Over 99 per cent. of the Indian silver production is obtained from the argentiferous lead-zinc ores of the Bawdwin mine, Northern Shan States, Burma. The reader is referred to the article on lead (page 154) for a description of the ores and their treatment at this mine. The remainder of the silver output is obtained from the gold ores of the Kolar field in Mysore and Anantapur in Madras (page 93); the contribution from these sources is insignificant compared with that of Bawdwin, as will be seen from Table 98 showing the silver production by localities.

In August, 1927, the North Anantapur Gold Mines Ltd. ceased operations, so that there is now no production from Madras. The output of silver from Kolar has remained well below the average for the four years preceding the period under review, whilst that from Bawdwin has shown a substantial and growing increase.

The production of silver in the world during 1926, was 253 million fine ounces, India's contribution being a little over 2 per cent. of the total. In 1924, India occupied the sixth position amongst the leading silver-producing countries of the world; in 1925, she fell to the seventh and in 1926, to the eighth place; in 1927, she regained the sixth place, cognisance not being taken of Germany for which figures are not available. The Bawdwin mine is the largest individual producer of silver in the world. India remains the largest single consumer of silver in the world, the net imports of the metal having averaged 98,193,791 ounces of an average value of Rs. 16,89,15,452 during the period under review.

The market price of silver per standard ounce. as quoted in London, has shown considerable variation during the 1924-28 quinquennium. The period opened with the price fluctuating between 36 and 31 pence per fine ounce. It then gradually fell to $24\frac{1}{8}$ pence per ounce towards the end of 1926, and at the same time the limits of fluctuation contracted. At the close of the period the price was fairly steady between 26 and 27 pence per fine ounce.

It was announced in August, 1927, that the total stock of fine silver held in the Paper Currency reserve, amounting to approxi-

TABLE 98.—*Quantity and value of Silver produced in India during 1924 to 1928.*

	Average for 1919 to 1923.		1924		1925		1926	
	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*
	Ozs.	*Rs.*	Ozs.	*Rs.*	Ozs.	*Rs.*	Ozs.	*Rs.*
Burma—								
Northern Shan States	3,527,825	*84,37,096*	5,287,711	*1,12,26,868*	4,831,548	*93,36,580*	5,103,646	*88,49,722*
Madras—								
Anantapur	579	*1,332*	249	*493*	21	*38*	59	*94*
Mysore—								
Kolar	(a)31,235	*73,283*	21,243·4	*43,725*	24,853·3	*46,571*	22,383	*35,222*
TOTAL	**3,559,639**	*85,11,711*	**5,309,203·4**	*1,12,71,086*	**4,856,422·3**	*93,83,189*	**5,126,088**	*88,85,038*
	..	..	..	*£810,869**	..	*£705,503†*	..	*£663,063‡*

	1927		1928		Average for 1924 to 1928.	
	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*
	Ozs.	*Rs.*	Ozs.	*Rs.*	Ozs.	*Rs.*
Burma—						
Northern Shan States	6,004,437	*94,67,196*	7,404,728	*1,19,26,055*	5,726,414	*1,01,61,284*
Madras—						
Anantapur	149	*125*	..	..	96	*150*
Mysore—						
Kolar	20,220	*31,220*	21,082	*32,916*	21,956	*37,931*
TOTAL	**6,024,806**	*94,98,541*	**7,425,810**	*1,19,58,971*	**5,748,466**	*1,01,99,365*
	..	*£708,846‡*	..	*£892,460‡*	..	*£756,148*

(a) 1919 not included. *(£1 = Rs. 13·9). †(£1 = Rs. 13·3). ‡(£1 = Rs. 13·4).

mately 9,000,000 fine ounces, had been sold. When the price of silver rose to 28¾ pence in May, 1928, it was announced that opportunity would be taken to sell silver from the Paper Currency reserve in special quarters for delivery in instalments. This announcement followed a very careful examination of the whole question of the disposal of the surplus silver coinage in India. The examination demonstrated the fact that it would be necessary to refine the silver, there being no demand for the 917 per mille alloy used for rupee coins. In their report dated January 25th, 1928, the Standing Finance Committee recognised that the process used in the Indian mints for silver refining was unsuitable for the new work, the cupelling furnaces being intended for small scale operations, and mainly for the refining of silver recovered from mint drosses. It was decided that the electrolytic process was simple and quite suitable for Indian conditions, and that what was known as the horizontal system, exemplified by the Balbach type of cell, had important advantages over others, namely, simplicity of operation, facility with which deposited silver could be collected without disturbing the cell elements, and the convenience and economy of being able to refine silver coin without previously melting. It was therefore proposed to set up an electrolytic refinery on the Balbach system at the Bombay mint.

Government Silver Refinery.

We are indebted to Major A. J. Ransford, Officiating Mint Master for the following note, transmitted through the courtesy of the Controller of the Currency, on the operation of the refinery in Bombay.

The silver refinery project was sanctioned by the Government of India in October, 1927, and orders for the necessary plant were issued at once. The buildings were commenced in April, 1928, and the refinery started work in March, 1929. The buildings consist of a three-storied silver nitrate building, and a large single-storied cell room, divided into silver and copper cell rooms, generator room, and chloride reduction room.

The top floor of the silver nitrate buildings is used as a nitric acid store, from which nitric acid is syphoned through acid-proof steel tubes to vats on the first floor, situated above the silver nitrate retorts. These consist of steam-jacketted acid proof 'ironac' vessels into which unrefined silver (rupees or silver recovered from chlorides, desilverising vats etc.,) is placed. Acid is allowed to run in slowly, and the resulting red fumes are removed by a vacuum

pump, through a system of catch pots, condensing pipes and washing towers, where any traces of silver and most of the nitrous oxide fumes are removed, converting the washing water to dilute nitric acid, which in turn is used in the ironacs for making more silver nitrate.

After about eight hours, the action ceases, and silver nitrate is syphoned off to settling vats, from which, when cool, it is run down to storage vats on the ground floor.

The silver cells are arranged in three groups, each group being connected in series parallel to a separate motor generator giving approximately 500 amps. at 50 volts. The cells are arranged on the Balbach system, the kathodes and anodes being arranged horizontally. The kathode consists of graphite plates fitted to the bottom of the cell, connected in circuit by a fine silver 'foot.' The anode consists of rupee coin spread loosely on a wooden tray lined with filter paper, at the top of the cell, connected in circuit by a standard silver 'foot.' The electrolyte is dilute silver nitrate.

Pure silver in a finely granulated form is deposited on the kathode, whence it is removed by scraping three times in 24 hours, washed with hot water, dried by hot air, and finally melted and cast into commercial ingots. The fineness is usually between 999 and 1,000 per mille. Copper and other base metals go into solution in the electrolyte ; gold and platinum, if any, are deposited with the dirt, as a black sludge on the filter paper. The accumulation of this sludge raises the resistance of the cells, and when the voltage of the group rises to about 70 volts, it becomes necessary to clean out the trays, removing and washing the sludge, which is dried and melted, and the precious metals recovered.

When the copper content of the electrolyte rises to 12 or 13 per cent. copper is deposited with the silver on the kathode, reducing the fineness of the output. The electrolyte is then pumped from the cells to a number of desilverising vats filled with pure copper strips, upon which the whole silver contents is duly deposited as a fine white powder, known as 'cement silver'. This deposit, when washed and melted, is of sufficient fineness to be used again in the ironacs, to make silver nitrate.

When quite clear of silver, the liquor which now consists of a 12 per cent. solution of copper nitrate is diluted to about 8 per cent. and then syphoned off to the copper cells. These are arranged with

vertical anodes and kathodes, the former being of fused magnetite, and the latter of pure copper. On passing an electric current through the copper cells, copper is deposited on the kathodes, the copper contents dropping in about three days from 8 per cent. to 1 per cent. and the nitric acid content rising to about 14 per cent. The nitric acid thus formed is pumped to the top floor of the nitrate building, whence it is run down to the ironacs, to make more silver nitrate. The copper kathodes are melted and cast into bars, fresh kathodes being rolled out as required.

Base metals such as lead, iron, nickel and zinc accumulate in the liquor during the continuous circle of operations, and when these rise to the point when the silver deposit is affected, the liquor from the copper cells, after forming silver nitrate, is passed to a concentrator. This consists of a set of double acid proof tubing, the liquor passing through the centre, and steam passing outside. The concentrated liquor is then allowed to cool and crystallise, the silver nitrate crystals thus obtained being used in the silver cells, while the mother liquor, after being completely desilverised with salt solution, is run to waste.

There remains the treatment of the water used in washing the fine silver deposit. This is run into chloride vats, treated with salt solution, and the silver chloride thus obtained is reduced with scrap iron to cement silver, which is then passed to the ironacs to make silver nitrate. The washing water is run off to sumps filled with scrap iron, where the last traces of copper and silver are removed, and the water run to waste.

A small laboratory is attached to the refinery, where rough tests of the silver and copper liquors are carried out, more accurate tests being provided by the assay office as required.

The plant is run continuously seven days a week, and will be shut down for about three or four weeks in each year for clearing up and computing losses. The chief trouble to be overcome is erosion caused by acid fumes, dilute nitric acid, silver nitrate and chloride. Acid-proof steels and irons have proved themselves efficient in resisting erosion, but will not stand the action of salt solutions or chloride. Brickwork even protected by asphalt is not acid resisting, and has had to be replaced by special acid resisting bricks obtained in England. Pumps, lift, fans and other machinery require special protection against acid fumes.

Arrangements have been made to refine silver for the public, as required, though no actual details of cost have yet been worked out. These costs will be determined after the Christmas overhaul. The charges for refining silver have been fixed provisionally as follows :—

	per 100 tolas gross weight. Rs.
For silver of 900 fineness or over	1-3-0
„ 850 to 899·9	1-5-0
„ 800 to 849·9	1-7-0

Silver below 800 fineness is not accepted. The above charges include all losses in refining, melting and casting into bars, but not the loss in pre-melting for assay. Fine silver is issued to the public, on the assay report, within 3 or 4 days of receipt of the silver to be refined. The bars turned out from the refinery are all of 999 fineness or over, of good appearance, and of approximately 1,000 to 1,200 ozs. weight. They are stamped with the Mint mark, a melting number for reference, fineness, and weight both in ounces and *tolas* to one place of decimals.

Although the costs of repairs are somewhat heavy owing to the continual erosion, there appears to be no reason why the plant should not last 20 to 30 years, without any extensive replacements.

Tin.

[J. COGGIN BROWN.]

Tenasserim deposits.

The cassiterite deposits of Burma, which furnish practically the whole of India's production of tin have been worked from a remote antiquity, especially in the districts of the Lower Tenasserim division. The region

through which the Burmese tin ore is disseminated, corresponds exactly with that described in another section of this review in the case of wolfram, for the ores of tungsten and tin are most intimately associated and are of identical origin. The granitic mountain ranges of Lower Burma are the northern continuation of the same rocks which have yielded the rich and well-known tin-stone deposits of the Malay Peninsula and Western Siam. The sporadic occurrences of cassiterite in India proper are not of any economic importance.

Production.

It has again to be recorded that although the ores of tin and tungsten occur in such close association in the parent veins of the Tenasserim division and although the prices obtainable for wolfram concentrates have ranged unusually low in the world's markets for the whole period under review, these conditions have not interfered with the steady growth of the tin industry which, if not spectacular, is, none the less real.

The difficulty mentioned in earlier reports of deciding on the approximate composition of the mixed tin and tungsten concentrates, though still in existence is not so pronounced now as formerly, for an increasing proportion of the tin ore output is obtained by dredging and other hydraulic methods, which yield a product practically free from wolfram, while most of the mineral obtained from general mining operations of all kinds is submitted to magnetic treatment for the separation of the wolfram before export

There has been no recorded production of block tin for the whole of the quinquennium and it appears therefore that the Chinese practice of smelting tin ore in Mergui before export has entirely ceased. For the previous quinquennial period (1919-1923), an average of 138 tons per annum was made.

The total output of Burmese tin concentrates has risen from 1,880 tons valued at Rs. 28,93,695 in 1924, to a maximum of 3,548 tons valued at Rs. 61,01,858 in 1926, falling again to 2,780 tons of a value of Rs. 45,41,201 in 1928, being an average of 2,802, valued at Rs. 47,43,602 per annum for the period 1924-28. Table 100 shows how this compares with the two former periods:—

TABLE 99.—*Quantity and value of Tin-ore produced in India during 1924 to 1928.*

Year.	Amherst.		Mergui.		Southern Shan States.		Tavoy.		Thaton.		Total.	
	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*
	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*
1924 .	3·7	*5,696*	439·1	*8,21,982*	..	..	1,433	*20,61,107*	4	*5,000*	1,879·8	*28.93.695*
1925 .	2	*3,800*	621	*10,47,511*	..	..	1,680	*25,06,170*	5	*6,000*	2,308	*35,63,481*
1926 .	..	..	703	*12,86,522*	972	*16,71,840* (a)	1,861	*31,22,496*	12	*21,000*	3,548	*61,01,858*
1927 .	..	..	1,163	*26,04,760*	836	*15,82,548* (a)	1,489	*24,15,465*		*15,000*	3,495	*66,17,773*
1928 .	9	*10,917*	1,052	*19,05,857*	(b)	(b)	1,712	*26,15,122*	7	*9,305*	2,780	*45,41,201*
Average .	*2 9*	*4,065*	*795·6*	*15.33,326*	*362*	*6,50,876*	*1,635*	*25,44,072*	*7*	*11,261*	*2,802·1*	*47,43,602*

(a) Estimated.
(b) Excludes 218 tons of low grade wolfram-scheelite-cassiterite ore valued at Rs. 53,841 from Mawchi.

TABLE 100.—*Growth of Tin ore production in Burma.*

Quinquennial periods.	Average annual output of concentrates.	Average annual value.
	Tons.	Rs.
1924-28	2,802	47,43,601
1919-23	1,854	23,32,747
1914-18	483	7,62,600

When it is remembered that the Mawchi mine in Karenni was idle for the greater part of the period and for three years showed nothing in the annual returns, these figures become all the more satisfactory, especially if the difficulties and delays which have been encountered in opening up new dredging concessions in isolated localities are taken into consideration, together with the world-wide fall in the price of the metal in recent years.

TABLE 101.—*Consumption of foreign block Tin in India.*

Year.	IMPORTS.		Re-exports.	Consumption.
	Quantity.	*Value.*		
	Cwts.	Rs.	Cwts.	Cwts.
1924 . . .	48,474	*78,34,317*	4,257	44,217
1925 . . .	55,259	*94,73,119*	7,224	48,035
1926 . . .	51,023	*94,72,957*	2,231	48,792
1927 . . .	60,529	*1,16,72,352*	485	60,044
1928 . . .	56,316	*92,22,619*	3,705	52,611
Average . . .	*54,320*	*95,35,073*	*3,580*	*50,740*

The consumption of metallic tin, imported in the unwrought form of blocks, ingots, bars and slabs, continues to increase in India. The average annual quantity amounted to 2,716 tons valued at Rs. 95,35,073 for the period 1924-28, compared with 2,137 tons valued at Rs. 65,95,716 for the previous quinquennium. Ninety-seven per cent. of this metal came from the Straits Settlements. It is perhaps legitimate to enquire whether it would not be profitable to smelt tin ore in Burma instead of exporting it abroad and then importing the metal again into the Indian Empire, particularly in a country where some new industries have been given protection in the form of import tariffs on their products.

Consumption.

During the progress of the systematic geological survey of the Mergui district tourmaline-muscovite-pegmatites, locally carrying cassiterite but never wolfram, have been found in various places cutting both the granites and sedimentary rocks into which they are intruded.

Mergui district.

Full details of these will be found in a memoir on the geology of the Mergui district by the late Rao Bahadur Sethu Rama Rau which is now in the press.

Both cassiterite and wolfram display a tendency to deposit in thin stringers or leaders, and little veinlets, half-an-inch or so in thickness, are often found which reproduce the internal structures of large veins. Such stringers are often excessively rich for their size and patches of ore occur in them which are practically solid. When such veinlets occur in close association in soft ground, they may form a valuable source of these ores. Much of the so-called 'alluvial' concentrate won by sluicing residual or decomposed rock is derived from the very numerous stringers and mineralised cracks penetrating such rock both in Mergui and Tavoy.

The size of the grains of Burmese stream tin depends entirely on the distance the mineral has travelled from its original home. In the upper parts of the valleys, where little classification of the river deposits has taken place and where there is still much unsorted detrital matter, individual crystals of about the same size as a coffee bean, with their edges rounded, can be picked out of the finer material. Further down stream, smaller, rather angular fragments are characteristic, but in the real alluvial sands and gravels the fine concentrated ore develops a rounded form often recalling the appearance of gun-powder. Here it is associated

with magnetite, ilmenite, topaz, garnet and zircon, and sometimes with small amounts of monazite and gold.

Attention has been drawn in earlier reports to the Maliwun vein deposits. Originally worked by the Chinese and later by European companies, the mine was lavishly equipped with machinery, but it was never able to pay, and the hydro-electric generators with mill, compressor, hydraulicing plant and electric trams were quickly rusted in the jungle, while a gang of Chinese tributors returned to their former practices. The quartz veins and greisen bands at Maliwun are in granite very close to its margin with the Mergui sediments, and they contain much white mica and some pyrite, chalcopyrite and arsenopyrite. Tourmaline has also been recorded.

The question of searching beneath the sea for tin ore along the Tenasserim coast received some attention during the period under review and concessions for this purpose were granted by the Government of Burma along the shores of the southern part of the Mergui district. There is little doubt that alluvial deposits brought down by rivers traversing stanniferous rocks, and spread over the sea floor in the vicinity of their mouths must contain a certain proportion of cassiterite. Indeed submarine tin deposits have been profitably worked in Java and other eastern countries but up to the present, they have not been located in Burmese waters.

Amongst important events which took place during the period under review in the mineral industry of the Mergui district, the commencement of large scale dredging operations by the Thabawleik Tin Dredging Company, Limited, in 1926, on alluvial deposits about eight miles from Nyaungbinkwin, and of hydraulic mining by the Anglo-Burma Tin Company, Limited, in 1928, at a neighbouring locality, deserve especial mention.

Tavoy district.

Geological conditions in Tavoy district are much the same as those in Mergui. Granite intruded into an ancient sedimentary series forms the cores of the mountain ranges; quartz veins and pegmatites carrying wolfram, cassiterite, molybdenite, bismuth, bismuthinite, and a large variety of sulphides, cut through them both. These minerals occur also in the alluvial deposits of the hill-sides, where veins are undergoing degradation, and in the coarse unsorted debris of clay, rotten rock and boulders, which tend to accumulate at the heads of the flatter valleys. Cassiterite is found too in the water-sorted alluvial deposits, the gravels and sands o the lower portions of the streams.

Though Tavoy is primarily a wolfram-bearing region, there are areas within its boundaries which are richer in cassiterite than the rest and it is from these and from the gradual extension of dredging operations that increased production has been and will be recorded. The Tavoy Tin Dredging Corporation continued its prosperous career during the period. The early history of this pioneering concern was given in the previous review and it need only be added here that contiguous areas adjacent to the original leases have been added to the available dredging ground, while to the north the Shwe *chaung* concession has been proved to contain reserves of ore-bearing ground. Three dredgers are now at work on the Hindu *chaung*. The Corporation has also taken part in extended prospecting operations in both the Tavoy and Mergui districts and holds large interests in the following concerns, which have all come into existence, during the period. The Northern Tavoy Tin Dredging Company, Limited, which has leased large areas in and around the Heinze basin, already equipped with two dredges, one of which was built in Holland and towed out to Burma: the Thingandon Tin Dredging Company, Limited, which has a dredge operating on an alluvial flat on the Pauktaing river, 18 miles north-east of Tavoy town: the Theindaw Tin Dredging Company, Limited, which has installed a dredge on the river of the same name in the Mergui district.

In addition to the companies mentioned the Kanbauk (Burma) Wolfram Mines Limited is working two dredges and a sluicing plant at Kanbauk in the Tavoy district; the Anglo-Burma Tin Co., Ltd., has installed monitors and hydraulic elevators on their Heinda area; the Kamounghla Tavoy Tin Company, Limited, has been formed to work certain alluvial tin-bearing deposits in the valley of the Maungmeshaung *chaung*, while the Consolidated Tin Mines of Burma Limited has taken over the properties of a number of lessees in the central portion of the district. It will be remarkable if these and other concerns do not make their influence apparent in an increased output of tin concentrates from Tavoy during the coming quinquennium.

Amherst district.

The output of tin ore from the Amherst district continues to be negligible and only averaged 2·9 tons per annum for the period. The geological survey of the district has been continued intermittently during the period and the metamorphic aureoles around the intrusions of the local granites have been proved to carry tourmaline and veins of tourmaline

micropegmatite which in places bear quartz stringers with cassiterite. In addition to the localities mentioned in the previous report, occurrences of tin ore have been sporadically worked in lateritic talus deposits at Thetkaw and at Sakangyi while a small pegmatite vein traversing shales and sandstones and containing black cassiterite is known at Kunhnitkway.

Thaton district.

The output from the Thaton district continued to be very small and only averaged seven tons per annum.

Southern Shan States.

A complete reorganisation of the Mawchi Mines took place towards the end of the period under review and at the same time a new programme of development has been initiated by the driving of two main low level cross-cut adits, the first of which has already intersected all the lodes in the western section of Mawchi hill. The company reports that both widths and values in wolfram and tin-stone are satisfactory at this depth. Additional hydro-electric power has been provided, steps have been taken to improve the transport routes, which connect the mine with the sea-board, and it is anticipated that with the resumption of milling activities at Mawchi, the output of both wolfram and tin-stone from the Southern Shan States will show a marked increase in the coming quinquennium.

Indian occurrences.

Cassiterite is known to occur in the Hazaribagh district of Bihar and Orissa and insignificant quantities of the ore have been returned from this locality in previous periods. They are believed to have been derived from the Nurunga deposits where the mineral is found in a cassiterite granulite. Both this and the further occurrences of Pihra and Domchanch in the same district, though of some scientific interest possess no economic importance.

Tungsten.

[J. Coggin Brown.]

History.

The earlier records of the occurrence of wolfram, a tungstate of iron and manganese, in Burma, date back to the forties of the last century and refer mainly to the efforts of misguided enthusiasts to extract tin from the mineral. These early experiments were completely forgotton in the course of time and it was not until 1908 that wolfram was redis-

covered by a member of the Geological Survey of India. From that time onwards the industry slowly developed through many vicissitudes until Burma headed the list of the world's producers, a position which she occupied in 1914 when the world War broke out and found the British Empire dependent upon Germany for supplies of tungsten—the metal which is so essential for martial operations. The measures which were taken to deal with this unprecedented situation and the degree of success which they attained have been described in earlier reviews. It is only necessary to recall here that the average annual output for the years 1914-18 was 3,473 tons. A period of stagnation followed and the next quinquennial period (1919-23) only registered an average of 1,726 tons per annum, valued at Rs. 15,80,725, for reasons discussed in its review. During the last quinquennium tungsten mining in Burma has gone from bad to worse and the average annual output for the years 1924-1928, was only 955 tons, valued at Rs. 4,86,752, most of which was probably obtained as a by-product in mining operations conducted primarily for the recovery of tin ore.

In the last review reference was made to the extraordinary history of China as a wolfram producing country, which quickly put her in the first place of the world's list. The world's production of tungsten ores to-day may be taken as approximately half that of the war period, but China still dominates the situation with a production far in excess of that of any other country, in spite of her own political upheavals. On the whole the world's market for tungsten ores has been stagnant and neglected, yet prices have shown some tendency to rise viewing the quinquennium as a whole. Thus in 1924, 65 per cent. WO_3 ores only averaged 10 or 11 shillings per unit, while during 1928 the average was probably nearer 16 shillings, with the higher prices in evidence towards the later months. These prices nevertheless compare very unfavourably with the 55 shillings per unit received during the war, and it is doubtful if wolfram mining, except as an adjunct to the tin industry, will show much improvement in Burma, unless and until prices rise considerably.

Production.

As the following table shows, the Tavoy field maintained its earlier predominating position, though it is possible that its production would have been beaten by the single Mawchi mine in the Southern Shan States had this been in operation throughout the whole of the period instead

of for two years only. The mixed concentrates from the Mawchi mine are exported in that state and are not separated completely in Burma. For the years 1926, and 1927, during which returns were made, it has been assumed for the purpose of this review that they contained 43 per cent. of wolfram and 57 per cent. of cassiterite.

TABLE 102.—*Quantity and value of Tungsten ore produced in India in 1924-28.*

Year.	MERGUI.		SOUTHERN SHAN STATES.		TAVOY.		TOTAL.	
	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*
	Tons.	Rs.	Tons.	Rs.	Tons.	Rs.	**Tons.**	Rs.
1924 .	0·3	*91*	..	..	738·7	*3,41,290*	**739·0**	*3,41,381*
1925 .	..	..	..	..	772·2	*4,51,864*	**772·2**	*4,51,864*
1926 .	9	*5,618*	733	(a) *3,58,999*	742·0	*4,06,347*	**1,484·0**	*7,70,964*
1927 .	8	*4,070*	630	(a) *3,09,330*	522·0	*2,56,603*	**1,160·0**	*5,70,003*
1928 .	29	*11,697*	..	..	593·0	*2,87,852*	**622·0**	*2,99,549*
Average	9·2	*4,295*	*272·6*	*1,33,666*	*673·6*	*3,48,791*	**955·4**	*4,86,752*

(*a*) Estimated.
(*b*) Excludes 218 tons of low grade wolfram-scheelite-cassiterite ore purchased for Rs. 53,841 from Mawchi.

Occurrence in Burma.

Quartz veins containing wolfram have been found at intervals over a distance of 750 miles in Burma from Yengan and Mawnang states of the Southern Shan States through the districts of Kyaukse, Yamethin, the state of Karenni, Thaton, Amherst, Tavoy and Mergui. In all these localities the wolfram and cassiterite-bearing veins are closely associated with a biotite boss-granite, which forms the core of the ranges of the Indo-Malayan mountain system stretching further to the south through Western Siam to the Malay Peninsula. The granite is intruded into a series of hardened and crushed shales, slates, argillites and agglomerates with greatly subordinate quartzites, limestones and conglomerates known as the Mergui series. These rocks are of unknown age, and are characterised by a monotonous uniformity of type over great areas and over an immensely thick mass of strata. In its typical exposures, though it varies consi-

derably in texture, the granite is extraordinarily uniform in composition. It contains abundant quartz, both orthoclase and acid plagioclase, while the mica is usually biotite. Towards the peripheries of the intrusions, the rock becomes finer-grained than the porphyritic and coarse varieties nearer the centres; biotite is scarcer, and muscovite takes its place. Hornblende is rare and accessory minerals are very uncommon. Pseudo-foliation is often developed near the contacts, and has led some observers to mistake portions of the rock for gneiss.

Both wolfram and cassiterite occur very sparingly as accessory minerals in the granite; they are also found in aplite and pegmatite veins traversing it and in the greisens, the narrow bands of quartz-mica rock formed by the alteration of the granite adjoining the true quartz veins. These modes of occurrence are of more theoretical interest than practical importance, and, with the exception of the surface deposits, quartz veins furnish the great bulk of the concentrates from Burma. Mineral-bearing quartz veins are found either in the granite, penetrating its contact with the sedimentary rocks, or enclosed within the latter rocks themselves at no great distance from the granite. The veins were formed by the infilling of fissures and often occur in parallel groups of overlapping lenses. The lenses themselves are often irregular, thinning out and thickening again, splitting and then re-uniting. There is every variation from great veins traceable for miles on the surface to mere stringers. The general strike follows that of the main mountain trend, and is N.—S. to N.E.—S.W. Dips are usually high.

In different parts of Burma, the mineral associates of wolfram are not the same. Beryl has only been found at Byingyi in the Yamethin district. Tourmaline is common at Mawchi in Karenni, in the Thaton district, and in parts of Mergui; in Tavoy it is unknown in conjunction with wolfram or cassiterite. Here, in addition to these minerals, the quartz veins carry mica (practically always), fluorite (often), molybdenite (sometimes), pyrrhotite (in some cases), galena (rare), zinc blende (rare), arsenopyrite (rare), native bismuth (rare), bismuthinite (rare), and topaz (in one case only). In the Tavoy district alone there were over 100 producing concessions in 1918, which ranged from shallow workings operated by primitive Chinese methods to deep mines, fully equipped with the most modern concentrating plants. The largest mines were

Hermingyi, Kanbauk, Widnes, Pagaye, Paungdaw, Taungpila and Kalonta.[1]

The chief wolfram deposits of the Mergui district are near Palauk in the north, and at Tagu near the Great Tenasserim river, some 70 miles from its mouth. The veins of the Tagu area are remarkable for their large size, varying from 3 to 15 feet in thickness; they are all in granite, and carry arsenopyrite and chalcopyrite. The veins of the Maliwun area, too, in the extreme south of Mergui district are in granite, but in the Palauk area the veins occur in both granite and sedimentary rocks.

The wolfram bearing veins of Thaton are in two well-marked series—one in granite, and the other in the sandstones of the long mountain ridge which runs parallel to the coast through this district. They differ markedly from those of Tavoy, in that they carry tourmaline. Four parallel veins, only a few inches thick, have been traced for the unusual distance of 2½ miles.

The well-known Mawchi mine is situated in the southern portion of the Bawlake state of Karenni. It possesses at least ten important veins varying from 2½ to 5 feet in thickness, which are all in granite. (*See* Tin.)

The wolfram-bearing area of the Yamethin district is situated close to the summit of Byingyi, a peak which rises 6,254 feet above sea-level on the borders of Yamethin and the Loi Long state. The veins are in granite, and carry wolfram, molybdenite and beryl.

In the concessions of the Myelat division of the Southern Shan States, granites, clay slates and quartzites are penetrated by veins carrying wolfram, molybdenite and copper, and iron compounds.[2]

Although further discussion is impossible here, it is hoped that the brief notes given will demonstrate clearly how closely all the wolfram and cassiterite deposits of Burma are associated with the intrusive granite already mentioned. It is believed that the deposits were formed partially under conditions closely allied to strictly magmatic ones, and were also produced by processes in which gaseous agencies, including compounds of fluorine and sulphur, to some extent played a part, and, in rare cases, by hydrothermal reactions which followed as a consequence of the former ones. Thus,

[1] See J. Coggin Brown and A. M. Heron, 'The Geology and Ore Deposits of Tavoy, *Mem. Geol. Surv. Ind.*, Vol. XLIV, Pt. 2 (1923).

[2] For fuller details see; 'The Distribution of the Ores of Tungsten and Tin in Burma, by J. Coggin Brown and A. M. Heron, *Rec. Geol. Surv. Ind.*, Vol. L, pp. 117—129 (1919), and 'A geographical Classification of the Mineral Deposits of Burma' by J. Coggin Brown, *op. cit.*, Vol. LVI., pp. 65-108 (1924).

the whole process of mineral-veins formation, associated with this great granite chain, appears to be a direct sequence of processes of differentiation or fractional crystallisation, through a varying series of phases, influenced by local conditions and induced in the original magma by decreasing temperature.

Indian occurrences. No output of wolfram was registered either from the Singhbhum district of Bihar and Orissa or from Marwar in Rajputana during the period under review.

Zinc.

[G. VERNON HOBSON.]

Zinc concentrates are produced at the milling plant of the Burma Corporation, Ltd., at Namtu, Northern Shan States. The zinc mineral is sphalerite occurring as an intimate associate of the galena at the Bawdwin mine. (*See* Lead.)

The origin of the zinc industry in India is of comparatively recent date and the progress made has been very substantial. During the quinquennial period, 1909-13, no production of zinc was recorded; during the period 1914-18, exports were returned as 11,973·6 tons up to 1916 and *nil* after that; the period 1919-23 marked a steady development with exports rising from a quarter of a ton in 1919, to 18,061 tons in 1922. There was then a set-back to 2,062 tons in 1923. The period under review has been marked by a steady and rapid increase in the output of zinc concentrates, as may be seen from the table accompanying this article. The slight set-back in 1925 was due to mine fires and therefore abnormal.

TABLE 103.—*Quantity and value of Zinc-concentrates produced during 1924-28.*

	Tons.	VALUE.	
		Rupees.	Sterling.
1924	18,650	*21,09,800*	151,784†
1925	16,810	*20,25,924*	152,325‡
1926	48,834	*63,24,491*	471,977*
1927	58,286	*73,19,468*	546,229*
1928	64,122	*74,96,118*	559,412*
TOTAL	206,702	*2,52,75,801*	1,881,727
Average 1924-28	*41,340*	*50,55,160*	*376,345*

†£1=Rs. 13·9. ‡ £1=Rs. 13·3. *£1=Rs. 13·4.

It was mentioned in the last review that the proposal to smelt the Burmese zinc concentrates at Jamshedpur, and to recover the sulphur in the form of sulphuric acid, had not eventuated. During the period, however, extensive investigations had been made into the most economical method of producing marketable zinc concentrates at Namtu. A special experimental flotation plant had been installed for the purpose, and it was anticipated that the regular shipment of Burmese concentrates in large quantities would become a feature to record in the future, unless the Indian sulphuric acid project were revived. The project has not been revived and the exportation of Burmese zinc concentrates has developed in a remarkable manner. The concentration mill at Namtu is now working in an efficient manner, the percentage recovery of zinc from current ore having been improved to 54·79 per cent. and a further improvement is looked for as a result of research work that has been in progress for some time. It is anticipated that the time will shortly arrive when a substantial selected portion of the lower grade ore reserves in the mine will be treated. This treatment will involve a considerable increase in the volume of material to be handled by the concentration mill with an increase in the out-turn of zinc concentrates as a natural corollary. The new construction work at the mill was already in progress at the close of the period under review and, in the absence of any restraining factors, a continued increase in the production of zinc concentrates in the future may be expected.

It was early realised by the Burma Corporation, Ltd., that with the rapidly increasing output of zinc concentrates there was a heavy and growing charge on account of the transport to Europe of the waste contained in these concentrates. An investigation was instituted to find out if the zinc concentrates could be used to better advantage. The first field of enquiry to be explored was that of treating the concentrates, and also the copper matte, locally for the production of refined metal, and the subsequent fabrication of the metals into commodities of general use. In this connection a source of power supply was a first essential and the report on the Yunzalin scheme for a water supply for Rangoon, coupled with power generation, was awaited with interest. The first report on this scheme presaged a price for power which could not be met by a refining industry, a figure not exceeding Rs. 50 per kilowatt per annum being stated as the maximum that such an undertaking could bear.

The quinquennial period now closed has seen the consummation of prolonged efforts to arrive at some agreement among zinc producers on a policy aiming at stabilisation of the market. A statistical bureau was set up in Brussels in May, 1928, followed by an agreement whereby production was to be curtailed if Continental stocks rose above a certain maximum or the London price for the metal fell below a certain minimum. This agreement was coupled with an arrangement for the restriction of American exports to parallel reduction of output elsewhere, the agreement to remain in force until June 30th, 1929. Up to the end of the period under review the agreement had had little material effect, though it may have had some demonstrative value.

The striking fact regarding zinc production throughout the world during the period 1924-28 has been the rapid and steady growth of output, with the result that overproduction has been a feature in this industry for some time. World production in 1921, was 439,648 tons; in 1924, the total had reached 1,002,538 tons; in 1927, the figure had increased to 1,305,371 tons and estimated production for 1928 was given as 1,365,357 tons. India occupied the ninth place in the list of producing countries for zinc ore for 1926, for which year complete figures are available.

The value of the market in India for wholly or partly finished zinc articles may be judged from the following figures showing the imports of zinc during the period under review. In 1924, imports were 5,369 tons valued at Rs. 27,39,234; by 1928 they had risen to 9,376 tons valued at Rs. 36,24,114. These figures do not include zinc imported in the form of its compounds, zinc white, or in alloys such as brass, under which headings imports must be quite considerable.

Zircon.

[W. A. K. CHRISTIE.]

Zircon, orthosilicate of zirconium, is a common accessory mineral in many granites and gneisses, and as such it is often found accompanying gravels and sands derived from such rocks. It is a constant constituent of the beach sands of Travancore. Fine crystals are to be obtained from some of the pegmatites of the Travancore state. Zircon is found in the nepheline syenites near Kangayam, Coimbatore district; in pegmatites at Kadavur, Trichinopoly district and near Domchanch, Hazaribagh district; and in

the Seitur graphite mine, Ramnad, Madras Presidency. Large clusters of crystals of a dark brown colour have been obtained from Abraki Pahar, Gaya district, Bihar and Orissa. A hydrated form resembling cyrtolite containing a small percentage of uranium is associated with samarskite in the Nellore district, Madras.

Zircon is recovered from the Travancore beach sands by the Travancore Minerals Company, Limited.

TABLE 104.—*Production of Zircon in Travancore in the years 1924 to 1928.*

Year.	Tons.	*Value.*
		£
1924	365	*2,717*
1925	576	*4,608*
1926	532	*2,987*
1927	1,465	*8,129*
1928	855	*4,267*

The sands, now chiefly worked for ilmenite, contain about six per cent. of zircon, which, together with rutile, is separated by gravity concentrators and magnetic separators at the company's works at Manavalakurichi (8° 8′; 77° 18′). Zircon is used for the preparation of zirconium oxide, a highly refractory material suitable for crucibles and high temperature cements. In 1928, zircon sand is said to have been sold in carload lots for 95 $ per ton.[1]

[1]H. C. Meyer; *Eng. Min. Jour.*, Vol. CXXVII, p. 95 (1929).

IV.—MINERALS OF GROUP II.

Alum and Aluminous Sulphates.

[C. S. Fox.]

Meaning of terms.

If the name alum is restricted to those double salts containing alumina, as the sesquioxide, with the sulphates of potassium, or sodium, or ammonium, and twenty-four molecules of water of crystallisation, then it can be definitely stated that no workable deposits of natural alum have so far been discovered in India. Of the other mineral substances, which can be grouped under the generic name of alum, there is no information to show that such material occurs in India in quantities which would justify exploitation. The potash alum, kalinite [$Al_2O_3(SO_3),K_2SO_4,24H_2O$] has been found in small quantities in some places. The mineral alunite [$3Al_2O_3(SO_3)$, $K_2SO_4,6H_2O$] has been noted in association with sulphur in the Sanni mines of Baluchistan. The natural substances alunogen [$Al_2O_3(SO_3)$, $18H_2O$] and aluminite [$Al_2O_3(SO_3)$, $9H_2O$], are not alums, but are largely used in some countries for the preparation of alum; however, so far as is known these minerals are not available from extensive domestic deposits for this purpose in India.

Manufacture.

Practically all the alum which is produced in India is made by the separation of sulphate of alumina from decomposed pyritous shales, with the addition of nitre or wood-ashes, to provide the hydrated double sulphates of alumina and potash, or of alumina and soda. At one time this was a relatively important local industry in certain parts of India, but the importation of cheap alum and the easy distribution of this article from the railways has resulted in the practical extinction of the native industry in most localities. Among the more important places where alum used to be manufactured may be mentioned:—Phulwaria in the Shahabad district of Bihar; Mhurr in Kachh (Cutch) and Maki Nai in Sind in the Bombay Presidency; Khetri and Singhana in Jaipur State in Rajputana; and Kalabagh and Kotki in the Mianwali district of the Punjab. To-day the only

locality in which alum is prepared on a commercial scale and from which returns are available is Kalabagh. A detailed account of the methods in use at this locality was given by the late Mr. N. D. Daru [*Rec. Geol. Surv. Ind.*, XXXVIII. p. 32, (1909); also XL, pp. 265-282, (1910)]. In the Salt Range near Kalabagh, alum shales are found at two distinct horizons in the Eocene (nummulitic) series, and again at the base of the underlying Jurassic series. Only one of these beds, situated at or near the base of the Eocene, is sufficiently rich in sulphur content to be used for alum making. The thickness varies from 7 or 10 feet at Kalabagh to 25 or 40 feet at the Chichali pass near Kotki, a distance of 9 miles. About a mile beyond the latter locality the bed appears to die out. The pyrites is disseminated through the shales in microscopic particles, and the proportion of sulphur varies greatly, from 2 to nearly 13 per cent. Workable shale, known as *rol,* contains an average of 9·5 per cent. of sulphur, and is distributed in patches through the bed. Mining is conducted on no systematic plan, but the mineral is extracted by means of narrow, tortuous passages, rendered unbearably hot by reason of the decomposition of the pyrites, and without any provision either for ventilation or drainage.

The shale brought from the mines is built up with layers of brushwood, and of clay that has been once burnt and exposed to the weather for at least a year, into heaps about 18 feet high, and roasted, fresh layers being added at one side of the heap, while the other is cut out for eaching. The burnt clay is added in order to absorb as far as possible the sulphurous fumes from the fresh shale, but much of the sulphur is lost by volatilisation.

The process of lixiviation is somewhat complicated. The roasted shale is steeped in water for two days in tanks (*gádán*), lined with a mixture of re-burnt wood-ashes, lime and cowdung, and the liquor is run into a settling tank (*chorh*), where it remains for 24 hours. In the meantime another portion of burnt shale has been steeped for 24 hours with some of the mother liquor from the crystallisation tanks in a smaller tank (*toi*). The solution from the *chorh* and *toi* are then boiled together for an hour in large iron pans, and run into a final settling tank (*nitar*), which is filled with the remainder of the mother liquor. After resting for 8 hours, half the contents of the *nitar* are boiled for 3 hours, when a certain proportion of *shora,* a mixture of chlorides, nitrates, and sulphates

of soda and of potash, with traces of carbonates, obtained from leaching out the efflorescent soil found at various places in the district, is added. Boiling is continued for another 7 hours, when the contents of the pan are transferred to a crystallising tank, and the pans are filled with the liquor remaining in the *nitar*. The crude crystals are removed after 5 or 6 days, and are purified by fusing them for 2 hours in their water of crystallisation. The liquor is finally crystallised in large earthenware jars half sunk in the ground.

It is interesting to compare the above description with that given for European practice, in Thorpe's Dictionary of Applied Chemistry, Vol. I. (1921), p. 176. Daru pointed out that the use of lime in the lixiviating tanks results in a very considerable loss of alum, and that this would be avoided by lining them with gypsum, which is found in abundance at Kalabagh itself. The product of the above manipulations is mainly soda-alum which is used at Delhi, Hissar, Sirsa, and other centres of the tanning and dyeing industries.

Pyritous shale suitable for the manufacture of alum has been noted in association with the coal seams of Makum, Lakhimpur district, Assam; Dandot colliery, Jhelum district, Punjab; and elsewhere in India. In view of the tendency to use aluminium sulphate in place of alum and its manufacture from bauxite it is likely that these pyritous shales will not be worked in an extensive manner in the near future.

TABLE 105.—*Indian production of Alum during the years 1919 to 1928.*

Year.	Quantity.	*Value.*	
	Cwts.	Rs.	£
1919	1,853	*48,000*	4,174(*a*)
1920	2,691	*73,200*	7,320(*b*)
1921	3,380	*64,400*	4,293(*c*)
1922	6,632	*99,760*	6,651(*c*)
1923	3,456	*64,472*	4,298(*c*)
1924	927	*18,900*	1,359(*d*)
1925	1,050	*22,848*	1,718(*e*)
1926	2,647	*50,400*	3,761(*f*)
1927	1,419	*23,160*	1,728(*f*)
1928	478	*5,525*	412(*f*)

(*a*) £1 = Rs. 11·5. (*b*) £1 = Rs. 10. (*c*) £1 = Rs. 15. (*d*) £1 = Rs. 13·9. (*e*) £1 = Rs. 13·3. (*f*) £1 = Rs. 13·4.

The annual production of alum during the past five years is given in the preceding table. The entire output is from the Mianwali district, Punjab.

TABLE 106.—*Imports of Aluminous Sulphates and Alum during the years 1919 to 1928.*

Year.	Alum.		Aluminous Sulphate.	
	Quantity.	*Value.*	Quantity.	*Value.*
	Cwts.	Rs.	Cwts.	Rs.
1919	51,915	*6,65,010*	64,312	*4,73,040*
1920	85,561	*10,18,270*	100,351	*7,65,280*
1921	38,235	*5,38,112*	47,272	*4,43,808*
1922	73,226	*8,75,198*	57,681	*4,65,371*
1923	68,094	*6,87,934*	56,275	*3,99,327*
Average	*63,406*	*7,56,905*	*65,178*	*5,09,365*
1924	66,152	*5,65,562*	67,898	*3,85,984*
1925	53,803	*3,95,069*	48,425	*1,89,852*
1926	62,348	*4,09,611*	70,901	*2,80,173*
1927	53,438	*3,47,702*	69,625	*2,77,096*
1928	52,172	*3,39,094*	63,924	*2,56,467*
Average	*57,583*	*4,11,408*	*64,155*	*2,77,914*

The above table shows that aluminous sulphates are on an average cheaper than alum. This point is of some importance in view of the fact that in most of its applications alum can and is being replaced by aluminium sulphate. In this connection it is interesting to note that fairly large quantities of sulphate of alumina are annually prepared in India by treating bauxite with sulphuric acid. Messrs. D. Waldie & Co. of Calcutta state that they use about 800 tons of raw bauxite annually in the production of 600 tons of alum cake; 1,000 tons of sulphate of alumina (15 per cent.); and 800 tons of alum, crystal, at their Konnagar and Cawnpore factories.

The substitution of bauxite for china clay in the manufacture of aluminium sulphate is fully discussed in Thorpe's Dictionary of Applied Chemistry, Vol. I (1921), pp. 171-173. It is there stated that the product of the china clay, 'alum cake', which is said to

average 12 to 13 per cent. soluble alumina and 0·12 to 0·22 per cent. ferric oxide, contains the whole of the silica, iron, and other impurities present in the clay and that 60 per cent. of the alumina present in the clay is converted into sulphate. 'Bauxite' has the advantage over china clay in that it is more readily soluble in sulphuric acid, needs no preliminary calcination and contains a larger percentage of alumina. It is subject to one drawback in that the average percentage of ferric oxide in the least ferruginous bauxites is comparatively large, as is seen in the accompanying analyses :—

	China clay.		Bauxite.		
	1. Belgaum, India.	2. St. Austell, Cornwall.	3 Co. Antrim, Ireland.	4. Dept. de Var France.	5. Chota Nagpur, India.
SiO_2 . .	44·00	46·20	13·0	15·8	1·32
TiO_2 . .	..	..	6·0	1·20	6·50
Al_2O_3 . .	41·30	41·10	42·00	66·50	60·49
Fe_2O_3 . .	0·50	0·20	2·00	2·10	2·01
H_2O (combined)	11·90	12·50	21·00	15·20	28·79

The commercial products known as 'alumino-ferric' and 'alferite', which are prepared by digesting crude bauxite with sulphuric acid, are used in the preparation of all but the finest papers, in the precipitation of sewage and refuse liquids, and in the clarification and decolorisation of water supplies. The pure aluminium sulphate is only made from pure alumina, and this substance is obtained directly from bauxite by the so-called Bayer process.

Amber.

[E. H. Pascoe.]

The production of Burmese amber during the five years 1924 to 1928 is shown in Table 107. The average annual production was 49·0 cwts. valued at Rs. 348 per cwt., compared with 31·44 cwts. valued at Rs. 352 per cwt. during the five years 1919 to 1923. The right to collect a 5-per-cent. *ad valorem* royalty on amber in the Myitkyina and

Production.

Upper Chindwin districts is farmed out with the jadeite royalties (See page 154).

TABLE 107.—*Production of Amber in the Myitkyina district, Upper Burma.*

	Quantity.	*Value.*	
	Cwts.	Rs.	£.
1924	89·3	*15,301*	1,101(*a*)
1925	16·1	*9,410*	710(*b*)
1926	39·5	*21,420*	1,599(*c*)
1927	70·6	*27,180*	2,028(*c*)
1928	29·5	*12,020*	897(*c*)
Average .	*49·0*	*17,072*	*1,267*

(*a*) £1 = Rs. 13·9. (*b*) £1 = Rs. 13·3. (*c*) £1 = Rs. 13·4.

Occurrence.

The Burmese diggings for amber are situated in the Hukong valley in the Nangotaimaw hills between Mainghkwan and Lalaung villages in about latitude 26° 20′ and longitude 96° 30′. The substance is found in pits from 20 to 40 feet deep, in blue clay of probably Miocene age; these pits are dug in a haphazard way and are occasionally joined up by underground connections. Fragments of amber have been similarly found in association with beds of this age in other parts of Burma, for example at Mantha in the Shwebo district, and are said to have been met with on the oil-field of Yenangyat in the Pakokku district. Where definitely known it is usually associated with lignite or coal. Most of the material is brought from the Hukong valley in Upper Burma to Mandalay, where beads for rosaries, *nadaungs* (ear-cylinders), and other trinkets for personal ornament are made from the transparent varieties.

Chemical and physical properties.

The amber of Burma differs in chemical and physical characters from previously known varieties and the name *burmite* has been consequently suggested for it as a specific distinction.[1] The well-knowm amber of eastern Prussia contains from 2½ to 6 per cent.

[1] O. Helm; *Rec. Geol. Surv. Ind.*, XXV, p. 180 (1892), and XXVI, p. 61 (1893).

of succinic acid and is known to the mineralogist as *succinite*. The Burmese amber is harder and denser, and it is doubtful whether it contains any succinic acid, though the products of its dry distillation include formic acid and pyrogallol; its ultimate chemical composition has been determined to be as follows:—

	Per cent.
Carbon	80·05
Hydrogen	11·50
Oxygen	8·43
Sulphur	0·02
	100·00

The specific gravity of burmite varies between 1·030 and 1·095. It is distinguished from many other amber-like resins by its superior hardness and greater toughness, which render it fit for carving and turning. It varies in colour from pale yellow to dull brown, and possesses a peculiar fluorescence, like that which distinguishes the Sicilian variety, *simetite*.

Apart from the occurrence of a large percentage of discoloured opaque pieces, many of the large fragments obtained are damaged by cracks filled with calcite; otherwise there appears to be a large quantity of material which might be put on the market with profit.

Arsenic.

[E. H. PASCOE.]

The chief indigenous source of arsenic is the orpiment mines of Chitral, where the mineral is exploited by the Mehtar of that country. Mr. G. H. Tipper, who recently carried out a survey of the State, reports that the orpiment is in most cases accompanied by realgar and fluorspar, and the mines, judging from the size and extent of the workings, are of considerable age. The six principal areas with their heights above sea-level are:—(*i*) Mirgasht Gol (11,000 feet); (*ii*) Aligot (13,000 feet); (*iii*) Londku (11,000 feet); (*iv*) Wizmich (16,000 feet); (*v*) Moghono Zom (15,000 feet); Stack (14,000 feet). The last four deposits are on the same line of strike. The arsenic

Chitral.

ore occurs close to a band of basic intrusive rock in calcareous shales associated with marble. The output of the mines fell off during the earlier years of the century and was less than 10 tons in 1905-06. No returns are available for recent years, although the industry is still carried on. The difficulties in working the present mines include the inaccessibility of the area, the inclemency of the weather, the unscientific lay-out of the mines and the lack of adequate ventilation. Mr. Tipper considers that there are good prospects of discovering fresh untouched deposits in Chitral.

Himalaya and Bihar.

A seam of arsenopyrite 1 foot thick, of which about two-thirds consist of ore, is recorded from the northern flank of Sampthar Hill near Darjeeling. A small outcrop of the same mineral is known to occur near Barali in the Bhutna valley, Kashmir. The occurrence of orpiment near Munsiari in Kumaon has long been known,[1] small quantities of this mineral and of realgar, the other sulphide, being sold in the bazars of northern India; but it was not till 1906, when Drs. G. de P. Cotter and J. Coggin Brown found scattered fragments of both minerals lying on the moraine material of the Shankalpa glacier, that any precise locality was ascertained. The ore was not found *in situ*, but had probably come from the hill-face immediately above.[2] Large lumps of leucopyrite, and arsenide of iron, have been found in the pegmatites of the mica-mining field near Gawan in the Hazaribagh district,[3] and other arsenides have been found associated with pyritous lodes in various places, but no attempt has been made to recover arsenic from these occurrences.

Exports and imports.

Details with regard to the production and use of Indian arsenic are not available, but there has been a considerable trade in both the Indian and foreign commodity, presumably in the form of white arsenic. Table 108 shows the extent of this trade for the period 1919-20 to 1923-24. Owing to the discontinuation of the old system of registration of trade by land and the introduction of a new system of registration from the 1st April, 1925, of selected commodities only and at certain selected railway stations adjacent to important land frontier routes, figures for the imports of arsenic including orpiment—are no longer available.

[1] A. W. Lawder; *Rec. Geol. Surv. Ind.*, II, p. 88 (1869).
[2] *Ibid*, XXXVI, p. 129 (1908).
[3] T. H. Holland; *Mem. Geol. Surv. Ind.*, XXXIV, p. 51 (1902).

TABLE 108.—*Average annual exports and imports of Arsenic (excepting Orpiment) for the years 1919-20 to 1923-24.*

	Quantity.	*Value.*
	Cwts.	*Rs.*
Exports of Indian Arsenic (except Orpiment)—		
To Bahrein Island	33	*1,448*
„ Straits Settlements	72	*2,869*
„ other countries	13	*727*
TOTAL	118	*5,044*
Imports of Foreign Arsenic (except Orpiment)—		
From United Kingdom	547	*26,324*
„ China (with Hongkong)	656	*49,239*
„ Straits Settlements (including Labuan)	66	*3,399*
„ other countries	299	*17,050*
TOTAL	1,568	*96,012*
Re-export of Foreign Arsenic (except Orpiment)	210	*9,028*

Orpiment, the yellow sulphide of arsenic, is largely imported into Burma from western China for use mainly as a pigment. During the five years 1919-20 to 1923-24, the average annual imports across this frontier amounted to 8,864 cwts. valued at Rs. 2,15,464 or Rs. 24·3 per cwt., as compared with 3,731 cwts. valued at Rs. 77,505 or Rs. 20·8 per cwt. during the five years 1914-15 to 1918-19.

Chinese orpiment.

The mineral is used as a pigment in the manufacture of Indian ornamental lac-wares and the Burmese lacquer-work; in the latter the favourite greens of the Pagan workers are produced by mixtures of indigo and orpiment, and the so-called gold-lacquer of Prome by powdered orpiment and gum. Orpiment is used also for the designs on the Afridi wax-cloths.

Asbestos.

[E. H. PASCOE.]

Attempts to develop asbestos in India have not yet met with any marked success on account of the inferior quality of the material in the deposits hitherto discovered. In 1910, 3 tons of asbestos valued at £6 were extracted in the Bhandara district, Central Pro-

vinces, presumably during prospecting operations; this source was recently given a fresh trial, yielding 7 tons in 1917 and 13 tons in 1918. The five years, 1919-1923, showed very little improvement; 9 tons were extracted in 1919, and 14 tons in 1922. The only output during the five years under review was one of 19·8 tons in 1924, valued at Rs. 1,876. In 1913, a small amount of work was carried out in the Hassan district, Mysore, where asbestos of fair quality is found in veins traversing actinolite schist, and the supply rose to 344 tons in 1918; this source continued to yield amounts of this order, and in 1920 produced as much as 1,711 tons valued at Rs. 68,440. No production has been recorded during the period 1924-28. Small outputs were recorded from the Bangalore district in 1920 and 1921, but none since the latter year. Some deposits in the Cuddapah district, Madras, have been worked during the five years under review by the Mysore Development Syndicate and yielded an average annual production of 16 tons, worth about Rs. 4,720. Two samples of this material from Rajupalem in the Kamalapuram *taluk* were recently forwarded to the Geological Survey laboratory and found to belong to the chrysotile variety. The better of the two samples compares well with the average Indian asbestos. Much of it, however, is less than one-tenth of an inch in length, the average being just under half an inch and the maximum less than one inch. It is said to fetch Rs. 200 a ton at the pit's mouth. The poorer quality sample is of shorter fibre still, averaging about 0·15 inch; it is reported as being sold for Rs. 75 per ton at the pit's mouth.

Several occurrences of asbestos were discovered during the period 1909-1913, of which two appeared to be of some size. One of these, near Dev Mori in Idar State, Bombay Presidency [1] contains a considerable amount of amphibole-asbestos in large rod-like masses yielding long-staple material up to 8 inches; hopes were at first entertained of this product but unfortunately it has proved to be too brittle. The other occurrence is in the Seraikela State, Singhbhum, the asbestos being of the amphibole variety, obtainable in long columnar masses, the more superficial portions suffering from the same defect of brittleness; it was found, however, that the quality improves with depth, as it does in Italy, and hopes have been entertained that this may prove to be the case in other localities also. The annual production from Seraikela between 1924

[1] C. S. Middlemiss; *Rec. Geol. Surv. Ind.*, XLII, pp. 53, 73 (1912).

and 1928, inclusive, was 64 tons. Increasing uses are being found for asbestos, as frequent enquiries indicate, so that there is every inducement for the exploitation of utilisable fibre.

TABLE 109.—*Production of Asbestos during the years 1924 to 1928.*

	1924		1925		1926		1927		1928	
	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*
	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*
Ajmer-Merwara . .	..	..	..	..	..	..	5·7	*1,150*	..	..
Bihar and Orissa—										
Seraikela . .	92·0	*11,550*	..	..	40·0	*5,000*	40·0	*5,800*	148·0	*20,460*
Central Provinces—										
Bhandara. . .	19·8	*1,876*	..	..	..	..	..	..	..	..
Madras—										
Cuddapah . .	13·5	*5,400*	16	*4,796*	18·4	*5,529*	22·0	*6,604*	8·5	*1,275*
TOTAL .	**125·3**	*18,826*	**16**	*4,796*	**58·4**	*10,529*	**67·7**	*13,554*	**156·5**	*21,735*
Total value in Sterling .	..	*£1,354* (£1 = Rs. 13·9)	..	*£361* (£1 = Rs. 13·3)	..	*£786* (£1 = Rs. 13·4)	..	*£1,011* (£1 = Rs. 13·4)	..	*£1,622* (£1 = Rs. 13·4)

Barytes.

[A. M. HERON.]

Barytes, or heavy spar, is the sulphate of barium, and finds its chief use in paint manufacture, owing to its cheapness, friability, inertness and low absorption of oil. Its function is not altogether as an adulterant of more expensive pigments, for a moderate proportion of barytes, increases the stability of white paints, and, in the case of certain dense and opaque coloured pigments, it acts

as an inert base, diffusing the colour by its presence and producing a brighter and clearer tint.

The greater part of the world's output is probably consumed in the manufacture of lithopone. This is a mixture of zinc oxide, zinc sulphide, and barium sulphate prepared by mixing solutions of barium sulphide and zinc sulphate. It has very largely replaced white lead as the basis of oil paints for use in interior decoration, and is also used in the manufacture of linoleum. Low grades of barytes can be utilised for making lithopone. Barytes is also used as a filler for paper, india-rubber and asbestos cement, and the other barium compounds, prepared from barytes or from the carbonate, witherite, have minor uses in the manufacture of oxygen and hydrogen peroxide, as chemical reagents, as glaze for iron and pottery, as water softeners, in luminous paint, and in pyrotechny. Although barytes is widely distributed through the Indian Empire, it is only from the deposits in Alwar State, Rajputana and near Betamcherla in the Kurnool district, Madras, that any real production has been obtained.

The figures of output are given below, with those for the imports of barytes into India :—

TABLE 110.—*Production of Barytes in India during the years 1924 to 1928.*

—	1924		1925		1926		1927		1928	
	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*
	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*
Madras—										
Kurnool . .	783	*11,341*	580	*7,760*	350	*1,400*	851	*5,550*	620	*4,610*
Rajputana—										
Alwar State . .	1,520	*20,000*	870	*9,900*	1,961	*7,844*	868	*4,340*	2,476	*15,000*
TOTAL .	2,303	*31,341*	1,450	*17,660*	2,311	*9,244*	1,719	*9,890*	3,096	*19,610*
Total value in sterling		*£2,255* (£1 = Rs. 13·9)		*£1,328* (£1 = Rs. 13·3)		*£690* (£1 = Rs. 13·4)		*£738* (£1 = Rs. 13·4)		*£1,463* (£1 = Rs. 13·4)

TABLE 111.—*Imports of Barytes into India.*

Year.	Quantity.	*Value.*
	Cwts.	Rs.
1923-24	8,780	*39,682*
1924-25	7,078	*28,692*
1925-26	21,828	*91,255*
1926-27	32,328	*1,17,807*
1927-28	33,862	*1,36,988*

Baluchistan.—Las Bela State. Concretions of barytes, with pyrites, are distributed through the Belemnite shales, on the Sarmowli river between Chad and Anjira, and near Pabni Chauki (25° 17′; 66° 58′), two days' journey from Karachi.[1]

Bihar and Orissa.—Ranchi district. A series of veins of barytes mixed with galena, runs through the villages of Silwai, Bahea and Bongibera, about 14 miles E. of Ranchi, in porphyritic granite.

Singhbhum district. Barytes has been recorded from the village of Kolpotha (22° 21′ 30″; 85° 5′ 30″), 4 miles N. N. W. of Jaraikela railway station on the Bengal Nagpur railway.

Burma.—Amherst district. Barytes, with galena and chalcopyrite, has been reported at Ayin *taung*, 15 miles south of Mitan, and other adjoining places on the Siam frontier.

Mandalay district. A bed of barytes 6 to 7 thick, was noted at Taung-gaung.[2]

Northern Shan States. Barytes in large quantities is found in the vicinity of the Bawdwin mines, and is used as a furnace lining by the Burma Corporation, Ltd.

Central India.—Rewah State. In the 'Red Shale' series of pre-Vindhyan age, veins of barytes from an inch to a foot in thickness were found by Vredenburg[3] near the village of Bharra (24° 23′; 82° 15′).

Orchha State.[4] According to Mr. M. K. Ray, barytes occurs with about equal quantities of quartz in a vein in Bundelkhand gneiss, and in the adjoining gneiss itself, by the side of a hill called Chakrada, within the limits of the village of Khura (now called Surajpura, 24° 43′ 30″; 79° 10′ 30″). This is 40 miles from the nearest railway station, Man Ranipur (G. I. P. Ry.). The vein

[1] G. H. Tipper; *Rec. Geol. Surv. Ind.*, XXXVIII, p. 214 (1909).
[2] H. H. Hayden; MS. notes (1896).
[3] *Mem. Geol. Surv. Ind.*, XXXI, p. 131 (1901).
[4] *Rec. Geol. Surv. Ind.*, LX, p. 431 (1928).

has been traced for a quarter of a mile and is 8 feet wide at one place. The barytes, at surface, is brownish white in colour, but improves at a depth of 2 or 3 feet.

Central Provinces.—Jubbulpore district. Barytes of poor quality occurs with lead and copper ores in Bijawar quartzite, about 2 miles North of the railway station at Sleemanabad (23° 38′ 30″; 80° 19′).

Madras.—Anantapur district. Barytes occurs in veins in the Vaimpalli slates and limestones, belonging to the Papaghni series of the Cuddapah system, in the reserved forest near Nerijamupalle (14° 32′ 30″; 78° 1′). Four veins have been found, the largest of which is from 3 to 11 feet wide and has been followed for more than half a mile along its strike. Another outcrop occurs in the Daditota reserved forest, 1½ miles north of the chief Nerijamupalle vein. The colour of the barytes is generally white, varying to light green and faint pink.[1]

Kurnool (Karnul) district. Probably the most important barytes deposits in India are those at Balapalapalle, 3 miles west of Betamcherla railway station (15° 27′; 78° 9′), where it has been quarried for use in paint manufacture. Other localities in this neighbourhood are 6 miles to the east of Gazulapalle railway station (15° 24′; 78° 35′) as the matrix in old galena mines, and at Jaladurgam (15° 17′; 77° 54′) and Chandrapalle (15° 13′; 77° 49′), near Dhone railway station.

Nellore district. Irregular veins of barytes, in mica-schists occur in two low hills 3 miles east of the village of Narravada (14° 54′; 79° 29′). The barytes is described by Jones[2] as opaque and of a greyish colour, with some of a milky colour on the lower slopes. It is often largely mixed with the mica-schist.

Salem district. Holland[3] has described an important occurrence of barytes in two low hills about a mile south of the village of Alangayam (12° 37′; 78° 49′), consisting of a network of veins composed of quartz and barytes, traversing gneiss. They vary in thickness from mere strings to dyke-like masses several feet across, and similar veins have been traced for a distance of 7 miles. The average proportion of barytes present is 30·8 per cent.

Rajputana.—Alwar State. Mr. S. K. Roy, State Geologist of Alwar, discovered 4 deposits of barytes in the state, at Bhankhera

[1] Coulson and Dey; *Rec. Geol. Surv. Ind.*, LX, p. 431 (1928).
[2] *Rec. Geol. Surv. Ind.*, XXXVI, p. 233 (1908).
[3] *Ibid*, XXX, pp. 236-242 (1897).

(27° 32′; 76° 38′), 3 miles S. W. of Alwar city, at Ramsinghpur (27° 10′; 76° 52′) 10 miles S. W. of Rajgarh railway station, at Jamraoli (27° 9′; 76° 44′), 10 miles S. E. of Rajgarh railway station and at Sainpuri (27° 46′; 76° 43′), 4 miles N. N. E. of Parisal railway station. The last mentioned is the most important, being pure white in colour, and forms a definite vein which has been traced for 110 feet and is about 15 feet thick. All are in the Alwar quartzites of the Delhi system.

Bauxite.

[C. S. Fox.]

Production.

The definite existence in India of workable occurrences of bauxite, now regarded as a highly aluminous type of laterite, was proved about the year 1905. Since 1910, there has been a small but increasing production of bauxite from the more favourably located Indian occurrences. The output during the period 1919-1928, is shown in the accompanying tables.

TABLE 112.—*Production of Bauxite during the years 1919 to 1928.*

Year.	Quantity.	*Value.*	
	Tons.	*Rs.*	£
1919	1,682	*19,343*	1,682(*a*)
1920	6,299	*53,308*	5,331 (*b*)
1921	6,652	*49,201*	3,280 (*c*)
1922	4,919	*15,948*	*1,063 (*c*)
1923	6,547	*55,233*	3,682 (*c*)
Average	5,220	*38,607*	3,008
1924	23,228	*1,88,075*	13,531 (*d*)
1925	10,070	*84,055*	6,320 (*e*)
1926	4,956	*36,768*	2,744 (*f*)
1927	4,310	*28,240*	2,107 (*f*)
1928	14,667	*94,253*	7,034 (*f*)
Average	11,446	*86,278*	6,347

* Excludes the value of 932 tons.
(*a*) £1=Rs. 11·5.
(*b*) £1=Rs. 10.
(*c*) £1=Rs. 15.
(*d*) £1=Rs. 13·9.
(*e*) £1=Rs. 13·3.
(*f*) £1=Rs. 13·4.

The world's output of bauxite has increased from an average of 500,000 tons in the quinquennial 1919-1923, to upwards of 1,200,000 tons in last five years, 1924-1928. The chief producers are France (500,000 tons in 1927), the United States (average of 350,000 tons in the years 1924-1928), Hungary (said to be 240,000 tons in 1927), British Guiana (roughly 160,000 tons annually), Dutch Guiana (from 50,000 tons in 1924, to nearly 150,000 tons in 1927), Yugo Slavia (roughly 120,000 tons in 1927) and Italy (80,000 tons in 1927). A decade ago France and the United States produced over 70 per cent. of the bauxite of the world's output. To-day these two countries barely produce 50 per cent. The greatest development has taken place in the Guianas—in 1917 the British colony first exported a small quantity—to-day the exports are almost equal to the production of the United States. Previous to 1919, the output from Dalmatia and Istria were given under Austria and the quantities were relatively insignificant. Since 1920, the output from Dalmatia has been included in that of Yugo Slavia, and the production from Istria is now part of the output of Italy. Compared with these great producers the Indian output is almost negligible in spite of the fact that the Indian bauxite occurrences are probably as rich in quality and abundant in quantity as any other known occurrences.

Prospects.

The domestic development of bauxite has so far been discouraging. It appears impossible at present to ship Indian bauxite to Europe at remunerative prices. Furthermore there is invariably some hitch in the negotiations, with regard to the samples and analyses which are shown, when the vendor is asked to guarantee, under penalty, that the shipments will be up to sample. Experience has shown that the vendors do not study the needs of the consumers and consequently do not realise the importance of strict attention to quality. Efforts have been made to float companies for the reduction of aluminium in India without due appreciation of the situation. It is insufficiently realized that in most cases in India electric power can only be obtained by the construction of elaborate and very expensive storage dams, that all the cryolite must be imported, and that the purification of the bauxite to alumina and the preparation of the high-grade carbon electrodes involves the working of specialised processes on a big scale. The aluminium production of the world is in the hands of only five great groups of producers, the output capacity of whose works is larger than the present demands

which they supply. These monopolistic firms have assured sources of supply as regards their raw materials, bauxite and cryolite. There are probably no cheaper sites for hydro-electric power than those they use. In addition to purifying their bauxite in alumina works owned by themselves, they possess factories for the manufacture of carbon electrodes, foundries for making alloys and castings, rolling mills for the output of sheets, circles, wire, etc. Finally they have excellent shipping facilities and their markets are not only established but cultivated. In the present state of the aluminium market such powerful organisations could not allow a new company of any pretentions to come into being. Such a venture might be successful if backed by overwhelming advantages, *e.g.*, cheap electric power, good quality bauxite in favourably located occurrences, assured supplies of cryolite, and a highly skilled staff for operating the alumina plant and making carbon electrodes. But if the Indian demand for aluminium be considered insufficient to justify this outlay and the Indian producer be unable to face competition, the general question of developing the bauxite resources of India, apart from the establishment of an aluminium industry, is one well worthy of attention. However, it is necessary that the requirements of the markets be studied and understood by the vendors of bauxite.

At the present time the world's production of bauxite, roughly 1,500,000 tons, is used in the following approximate proportions in several industries :—

	Per cent.
For aluminium after conversion to alumina	70
For the manufacture of chemicals	15
In the production of abrasives	8
For the preparation of refractories, for bauxite cement, for the purification of kerosene, and for other purposes excluding building stone	7

If the world's output of bauxite be taken roughly as 1,500,000 tons annually, it is evident that the quantities absorbed in the minor manufacturing industries are attractively large.

The accompanying Table gives the results of the chemical analyses of the bauxites of France, the United States, British Guiana, Italy, India and the Gold Coast. Detailed particulars of the bauxite occurrences of the world are given in 'Bauxite' by Cyril S. Fox (1927) and in 'The Industrial Uses of Bauxite' N. V. S. Knibbs (1928) discusses the world's consumption of bauxite,

The two main classes of ore are (1) the Mediterranean (*Terra Rossa*) type and (2) the Tertiary (*Lateritic*) type. Under the former class are included the bauxites of Spain, France, Italy, Yugo-Slavia and Rumania—types which seldom contain more than 14 per cent. of combined water and indicate a certain degree of dehydration. The latter class includes most of the bauxites of America, Africa, India and Australia; these deposits appear to be of a geologically younger type and average a combined water content of from 22 to 30 per cent. with a somewhat lower alumina content (54 per cent.) than the Mediterranean type.

Classification.

For commercial purposes it is convenient to classify bauxites into the following varieties:—

(*a*) *Normal bauxite.* Fair quality with 55 to 60 per cent. alumina, and high-grade ore with over 60 per cent. of alumina. Total impurities not to exceed 20 per cent., excluding the combined water content. The chief impurities, ferric oxide, silica and titania, each not to exceed 5 per cent.

(*b*) *White or siliceous bauxite.* To have upwards of 55 per cent. alumina and not more than 20 per cent. impurities excluding the combined water. Silica from over 5 to about 20 per cent. Ferric oxide less than 5 per cent. Titania up to 5 per cent. This class of ore is most frequently used for chemical purposes or the preparation of alum and other aluminium salts.

(*c*) *Titaniferous bauxite.* The alumina to average 55 per cent. and the total impurities excluding combined water not to exceed 25 per cent. Titania above 7 per cent. Silica less than 5 per cent. Ferric oxide not to exceed 10 per cent. These bauxites are rare except in India but have a great future before them owing to the valuable nature of the titaniferous slime which can be obtained as a by-product when the ore is purified by the Bayer process.

(*d*) *Red or ferruginous bauxite.* Alumina content to be upward of 52 per cent. Total impurities not to exceed 25 per cent. Ferric oxide between 10 and 25 per cent. Silica to be less than 5 per cent. Titania normally

TABLE 113.—*Analyses of Characteristic Bauxites.*

	France.				Rumania.		Dalmatia.	Italy.	
	1	2	3	4	5	6	7	8	9
1. SiO_2	0·80	0·80	0·29	13·3	1·49	0·80	0·89	2·79	7·91
2. TiO_2	2·80	3·50	0·80	2·4	3·12	2·80	—	1·27	—
3. Al_2O_3	58·6	76·4	60·60	63·7	59·66	65·5	51·85	57·6	58·86
4. Fe_2O_3	26·2	4·8	26·0	5·5	23·66	21·3	26·82	26·55	18·62
5. CaO	—	—	—	—	—	—	—	—	0·30
6. MgO	—	—	—	—	—	—	—	—	0·37
7. H_2O (comb.)	10·9	14·3	10·4	14·3	11·81	9·96	19·97	11·71	13·27

1 and 2. Loupain (Herault), analyses by M. Blot for M. Arsandaux. 3. and 4. La Caire (Var), analyses ditto. 5. Cucul (Bihar Mts.), analysis by M. Blot for R. Lachmann. 6. Dealul Cruci (Bihar Mts.), analysis ditto. 7. Dernis (Dalmatia), analysis by Kucan for Kispatic. 8. Lecce dei Marsi (Abruzzo), analysis given by G. Aichino. 9. Pietraroja, Benevento (Campagna), analysis given by Mattiralo.

TABLE 113.—*Analyses of characteristic Bauxites.*—contd.

—	United States.				British Guiana.		India.			Gold Coast.	
	10	11	12	13	14	15	16	17	18	19	20
1. SiO_2	2·90	7·91	10·13	0·62	2·73	1·00	1·18	1·44	0·30	1·72	0·62
2. TiO_2	3·40	3·50	—	1·05	0·10	1·10	8·80	6·32	7·40	1·89	1·66
3. Al_2O_3	58·21	62·05	55·59	64·91	64·38	70·90	60·23	62·32	66·98	64·40	59·05
4. Fe_2O_3	3·60	1·66	6·08	0·28	0·50	0·80	2·64	2·65	5·92	2·27	12·19
5. CaO	—	—	—	—	—	—	0·82	trace	—	—	—
6. MgO	—	—	—	—	—	—	0·30	0·38	trace	—	—
7. H_2O (comb.)	31·89	30·31	28·99	33·00	32·29	26·30	25·40	26·27	21·40	29·24	26·47

10. Cherokee Co. (Alabama), analysis given by H. McCalley. 11 and 12. Arkansas, analyses given by J. C. Branner. 13. Floyd Co. (Georgia), analysis given by T. L. Watson. 14. Yarikita River (British Guiana), analysis given by J. B. Harrison. 15. Essequibo River, analysis ditto. 16. Bargawan hill (Katni), Jabalpur District, analysis by R. V. Briggs. 17. Panhala Fort, Kolhapur State, analysis by R. V. Briggs. 18. Rajadera, Ranchi District, analysis Geological Survey, India Laboratory. 19 and 20. Mt. Ejuanema Bauxite (after A. E. Kitson).

less than 5 per cent. This variety of bauxite is most commonly used by aluminium reduction companies.[1]

Quarrying and mining.

In France the bauxite occurs interbedded with beds of Upper Cretaceous age. The outcrops can frequently be quarried by means of open pits but when the bauxite zone dips away to appreciable depths the material has to be mined in the same way as coal or other bedded deposits. Much of the bauxite in the Department de Var (France) is mined like gently inclined coal seams. Occasionally the bauxite bed is steeply inclined and necessitates the procedure in vogue in metal mines; a good deal is quarried in a normal manner. The bauxite of County Antrim (Ireland) is worked in the same way as the French ore. In Ireland the bauxite occurs as an aluminous laterite interbedded with the basaltic lavas of Ulster. The bauxite of Italy, Dalmatia and the Balkan area in general has been won by simple quarrying by hand.

In the United States of America the Arkansas bauxite, consisting of a gently inclined ore bed about 11 feet thick, which is overlain by loose sandy clay, is quarried. In Georgia, Alabama and Tennessee the ore occurs in irregular pockets which involve working by open pits; some ores require the use of explosives.

In British Guiana the bauxite at present being worked is exposed on the surface of the ground and merely requires digging out. The same is true for the bauxite occurrences of West Africa and India. In the latter country the greater number of bauxite deposits occur as segregations in the laterite which caps flat-topped hills and plateaux. These occurrences can be worked and kept free of water with little difficulty. There are localities in India, as in other countries, where bauxite occurs under loose material in low ground or interbedded with more massive strata. The removal of overburden or the de-watering of workings naturally increases the cost of the raw material but these factors may be offset by the favourable location of the deposit with regard to a railway or waterway.

Calcination.

It has previously been shown that raw bauxite contains from 10 to over 30 per cent. of combined water. As most bauxites require transportation over considerable distances to the place where it is utilised, it has become customary, particularly in the United States, for large producing

[1] *The Mining Journal* for Dec. 30, 1922, p. 986.

companies to get rid of some, or all, of the combined water by drying first. In Arkansas the ore from the mine is crushed or disintegrated and eventually roasted in rotary kilns. These kilns were once fired mostly by producer gas, but they have been converted to burn pulverised coal exclusively. The temperature used is probably about 1,100° F. (roughly 600° C.) and the mechanically held moisture is reduced to roughly 1 per cent.[1] A very similar procedure is employed in dealing with the bauxite of British Guiana.

Manufacture of alumina and aluminium.

The process at present commonly employed, both in Europe and America, for the manufacture of alumina from bauxite is known as the Bayer process. (See Aluminium, by, G. Mortimer, 1919, pp. 22-23). The whole plant is elaborate and expensive. There are, as may be imagined, many precautions to be observed to prevent waste, and great experience is necessary for the successful working of the plant. Very little of the caustic soda used is lost if the bauxite is properly corrected, and the ferric oxide sludge obtained in the first set of filters could be used as an iron ore or as paint material.

Almost all the aluminium of commerce is produced in some simple form of electric furnace such as the Hall Heroult, using 8,000 to 20,000 ampères at a low voltage (5 to 8 volts). In practice there are many pit-falls, and great care is necessary in the control and management of the plant. (See Aluminium, by G. Mortimer, 1919, pp. 29-40). The consumption of the carbon electrodes constitutes a large part of the expenditure, as they are made of the purest carbon (petroleum coke with tar for a binding material). The enormous current used necessitates cheap electrical power as a *sine qua non*, and a large scale production is almost certainly more economical than a small output. The manufacture of cheap electrodes of good quality requires consideration, as the impurities in the electrode, silica ferric oxide, etc., go into the metal and cannot be subsequently removed. Most of the cryolite used comes from mines in Greenland, but an artificial cryolite is now available. The market price for cryolite in the United Kingdom is £56 per ton, and this material would have to be imported into India.

For chemical purposes.

Under the article dealing with Alum and Aluminous Sulphates mention was made of the use of bauxite for the preparation of 'aluminoferric' and 'alferite', *i.e.*, crude aluminium sulphate. Attention was drawn to the

[1] *Engineering and Mining Journal Press,* Nov. 4, 1922, p. 807.

fact that pure aluminium sulphate was only made from pure aluminium hydroxide. These two pure substances, aluminium sulphate and hydroxide, are used as the basis of manufacture in preparing other aluminium salts, *e.g.*, aluminium chloride. Aluminium hydroxide possesses a powerful affinity for many organic substances, and enters into association with a large number of colouring matters, precipitating them completely as *lakes*. On this property depends the use of alum mordants. They precipitate the hydroxide upon the fibre of the goods to be dyed and this constitutes the fixing agent, or *mordant*, which retains the colour. Aluminium chloride (anhydrous) possesses great technical advantages in petroleum refining. It is largely used in the United States of America to convert all unsaturated into saturated compounds, thus converting unstable gasoline and lubricating oils (of asphaltic base) into excellent stable products of good colour and odour practically equal to paraffin-base products. It is expensive, however, and this factor prevents its use in oil purification on a very large scale.

For petroleum purification.

It has been known for many years that fuller's earth is capable of exercising a selective action on petroleum by retaining the unsaturated hydro-carbon and sulphur compounds which were in the oil. This remarkable property was utilised in oil refineries in the United States and other countries and the theoretical aspects of the phenomenon have been ably discussed in numerous papers. (See *Proc. Amer. Phil. Soc.*, 36, No. 154, 1897; Bulletin 315, *U. S. Geol. Surv.* 1907; Richardson and Wallace in *Journ. Soc. Chem. Ind.* for March 1912; and numerous other papers.) Investigation has shown that colloids such as alumina, bauxite, fuller's earth, etc., when freshly ignited (about 500° C.), acquire the curious property of actively attaching to themselves (on their surfaces) by absorption, other colloids and certain reactive substances. Colouring matter and sulphur compounds in particular are readily absorbed when kerosene is filtered through freshly treated bauxite.

This decolorisation and de-sulphurisation of mineral oil by fuller's earth, bauxite, etc., is said to be produced by physico-chemical action relating to surface tension. No reagent is necessary and no chemical interaction results although a slight rise of temperature has been noticed. Kerosene when filtered through graded bauxite of from 30 to 60 mesh, becomes water clear and, for practical purposes, free from sulphur. In process of time the bauxite in a filter becomes less active

but it can be rendered effective again by re-heating. Thus it appears that except for handling for re-heating and sieving there would be no loss of the bauxite, which can be used over and over again. Bauxite filters are now being installed in all modern oil refineries for the purification of kerosene. According to A. E. Dunstan (*The Petroleum Industry*, 1922, p. 182), Messrs. The Hall Motor Fuel Company have in recent years carried out this process in a slightly different way. By passing the vapour of petroleum over heated bauxite 'cracked' spirit, a most difficult substance to refine, is capable of simple and easy refining without any chemical treatment at all, and with the minimum of loss.

Considerable attention has been attracted to the fact that all kinds of bauxites are not equally efficient in the purification of kerosene. Also, much experimental work is in progress to discover why the most efficient kind of bauxite for kerosene purification is not equally effective in de-sulphurising petrol, and the reason for its failure when used for the purification of lubricating oil. Very little information is available regarding the results obtained in the recent investigations regarding the use of bauxite for the de-sulphurisation, etc., of all the petroleum distillates from light spirit to the stiff wax. The subject of the use of bauxite for petroleum purification has been carefully investigated by the research department of the Anglo-Persian Oil Company, and as a result two useful papers, 'Bauxite as a refining Agent for Petroleum Distillation' by A. E. Dunstan and others and 'Technical Use of Bauxite in connection with Petroleum Refining' by A. M. O'Brien, have been published (See *Jour. Soc. Chem. Indus.*, Vol. 43, No. 24, 1924, pp. 179T-189T). Until a bauxite is actually tested it appears difficult to say how efficient it may prove for the purification of kerosene. The chemical analysis gives practically no clue to its value for this purpose. So far, the Indian type of bauxite (with high combined water) appears to have proved most suitable and it is thought that this is due to the micro-cellular structure which must result when this bauxite is ignited preparatory to its use in the kerosene filter.

The demand for bauxite for oil purification becomes larger year by year and would be very considerable if bauxite was, by suitable thermal treatment, made capable of purifying all petroleum distillates as efficiently as it treats kerosene. The waste, chiefly as dust, in crushing, heating, sieving, re-heating, etc., although not

large at first, steadily accumulates so that perhaps some economy could be effected by collecting the dust and marketing it as 'bauxite dross.'

Decolorisation of sugar.

Bauxite has also been found suitable for the decolorisation of sugar and other hydro-carbon solutions so that a large field for research is open, the successful exploitation of which would create a further demand for bauxite. Colloidal alumina is thought to be more effective than either bauxite or fuller's earth for the desulphurisation and decolorisation of mineral oils, etc., so that it is possible that economy might be effected by preparing cheap pure colloidal alumina from bauxite.

Bauxite cements.

It has been known for several years that Portland cement deteriorates rapidly when exposed to waters containing sulphates. The failure is said to be due to the formation of sulpho-aluminate of lime. This substance combines with water and undergoes crystallisation with a large increase in volume. Experiments by the United States Bureau of Standards and by other investigators, particularly M. Bied in France, led to the preparation of high-alumina cements. These cements are essentially calcium aluminates low in silica. They have been manufactured by fusing together bauxite, coke and limestone, with occasionally slag or schist of suitable composition, in a small blast (cupola) or electric furnace. The fused product is poured, cooled and ground to make the finished product (see '*Engineering*' for August 11th, 1922, page 180). The prepared product has an approximate composition of 40 per cent. alumina, 35 to 50 per cent. lime, 8 to 12 per cent. silica and from 2 to 14 per cent. ferric oxide. No special quality of bauxite appears to be necessary, though the resulting cements are not equally efficient. The manufactured high-alumina cements are sold as 'fused cements', 'Lafarge cement', '*ciment électrique*', '*ciment fondu*', etc. '*Ciment fondu*' is being manufactured by the 'Société Anonyme des Chaux et Ciments de Lefarge et du Tiel,' who have works at Tiel and Montiers (Savoie). '*Ciment électrique*' is reported to be available from the 'Bureau d'Organization Economique' and it is manufactured by the 'Société des Produits Chimiques d'Alais, Forges et Camargue,' at their Argentiere works.

A considerable amount of attention was given to these cements during the Great War. High-alumina cements, because of their quick-setting properties and the fast development of their full

strength were used in the construction of heavy gun emplacements, 'pill-boxes', etc. However, for various reasons now known, these high-alumina cements did not fulfill the results then expected of them; they set too quickly and were rapidly affected to their disadvantage if contaminated with lime or Portland cement before or during use. Since the war they have been used, with certain precautions, and have proved of great value in difficult cases. Some of these uses have been for concrete piles, masonry exposed to sea-water, tunnels through strata contaminated with sulphates, in *caissons*, etc. The advantages this material possesses over Portland cement are its immunity from deterioration when exposed to sea-water or to waters or soils containing sulphate salts, and its rapidity of setting and attaining full strength. It is stated that in typical tests the tensile and compressive strengths obtained by high-alumina cements in a few hours were greater than those of Portland cement after several weeks. The following figures (quoted from '*Engineering*' of August 11th, 1922, page 180) are of interest: '*Ciment fondu*', tensile strength 59 kilograms after 48 hours and 71 kilograms after 28 days as against 55 kilograms in 28 days for Portland cement. The compression results were 687 kilograms per square centimetre in 48 hours and 959 kilograms in 28 days for '*ciment fondu*' as against 612 kilograms in 28 days for Portland cement.

The value of these physical properties will be at once evident to the civil engineer, and, although the present cost of the material is nearly double that of Portland cement, it must appeal to him as being the most suitable substance in every way for particular purposes. The high cost is largely due to the expense involved in fusing the raw materials. It is claimed that careful calcination is sufficient, but so far the best results have been obtained by fusing the raw material. The commercial preparation of this type of cement is still in its infancy and much is expected from the investigation now in progress. (See 'Industrial Uses of Bauxite' by N. V. S. Knibbs, 1928.)

Bauxite for abrasive purposes.

A substance which possesses the hardness of natural crystalline corundum could easily be marketed if it were possible to produce it cheaply and utilise it for the manufacture of grinding wheels, rubbing bricks, hone stones, polishing powders, etc. The best grades of natural pure corundum average from 95 to 99 per cent. alumina

with small percentages of silica and ferric oxide as impurities. A lower grade of corundum consisting of a finely intergrown mixture of corundum and magnetite crystals is the substance known as natural emery. Large occurrences of corundum and emery are not common and in consequence of the increasing demand for such material for abrasive purposes an important industry for the manufacture of artificial corundum and emery has developed. In the majority of these new works the raw material used is calcined bauxite. This ore is fused in an electric furnace of the arc type and the melt allowed to cool sufficiently slowly to become crystalline when solid. The solid 'pig' is then removed from the furnace, broken up and crushed, mixed with a suitable binder and made into the various types of grinders' tools, wheels, bricks, etc., required and these raw manufactured articles are burnt or baked in a kiln before being ready for the market.

There are several artificially prepared types of corundum and emery goods now available which have been made from bauxite in the general manner described above. It is obvious that the quality of the abrasive will depend on the quality of the bauxite used in its preparation. High-grade bauxite with little or no silica and no ferric oxide would give very high-grade corundum, whereas a ferruginous bauxite would invariably produce emery. On the market these artificially prepared corundum and emery goods bear the trade name of the manufacturers: thus 'aloxite', which contains upwards of 94 per cent. alumina, is made by the Carborundum Company, who have works at Niagara Falls and, to be near the French bauxite, at Sarancolin in the Hautes Pyrénées; 'alundum' is a very similar material and is prepared by the Norton Company of Chippawa in Canada and sold by them in two grades, 'white' and 'ordinary'; 'boro-carbone', is practically only another quality of aloxite and is also manufactured by the Carborundum Company in France and at the Niagara Falls but its sale is controlled by the Abrasive Company of Philadelphia, Pennsylvania.[1]

Bauxite refractories.

Owing to the large percentages of combined water in most bauxites it is necessary to calcine thoroughly the raw material before moulding it into bricks and other articles. A binding material such as fireclay is normally used in the manufacture of bauxite refractory goods. The finished ware, although capable of withstanding temperatures up to 1,800° C.,

[1] F. B. Jacobs; 'Abrasives and Abrasive Wheels,' 1919, pages 53—82.

have the objectionable properties of cracking with changes of temperature and shrinking as long as they are exposed to high temperatures. The bauxite linings of furnaces become very hard after heating and are consequently of value in rotary cement kilns where the lining is subject to considerable attrition by the gravitating charge. The quality of the bauxite used in the manufacture of various kinds of goods very greatly affects the melting point and slag-resisting power of the article. Ferruginous bauxites melt at about 1,600° C., or less. Siliceous bauxites are liable to rapid corrosion by basic slags. A bauxite high in alumina with very low percentages of ferric oxide or silica makes an exceedingly valuable basic refractory. If sufficiently calcined it becomes as hard as emery and is not subject to serious expansion when exposed to high temperatures. However, the high temperature of calcination makes this bauxite refractory somewhat expensive for general purposes.

High alumina refractories[1] are arbitrarily distinguished from other refractories containing alumina, by an alumina content of at least 58 per cent. Such refractories are ordinarily made from bauxite or bauxite and high-alumina clays (bauxitic clays, diaspore clays and similar material). Ordinary bauxite bricks are made by mixing calcined bauxite or high-alumina clay with a bonding material such as fireclay, sodium silicate, or lime, shaping by hand or by brick machines, and burning in various types of brick kilns at a high temperature. Another class of bauxite refractories is made by fusing bauxite in an electric furnace and casting the molten material in moulds. The demand for this type of refractories is increasing owing to the ever-growing need of better refractories. Pure bauxite melts at about 1,820° C. and pure alumina at about 2,050° C., but the lower grades of bauxite brick melt at 1,740° or less. The value of bauxite refractories depends upon their chemical inertness at high temperatures. In basic open-hearth steel practice bauxite brick should contain over 12 per cent. silica.

Recently high alumina refractories have been made more commonly from diaspore and high-alumina clays than from bauxite.

Bauxite specifications and contracts.

For many years the principal use of bauxite has been for the preparation of alumina and the subsequent reduction of this substance to aluminium. In a subsidiary way bauxite of a certain quality has been utilised in the chemical industry, and some bauxite

[1] *Eng. and Min. Jour. Press*, Vol. 114, No. 19, Nov. 4th, 1922, p. 809.

has been absorbed in the production of *alundum* and other substances. The chief users have usually possessed or leased bauxite properties so that there has been little or no buying and selling of bauxite in the open market. During the last decade, however, a considerable degree of attention has been devoted to the development of bauxite properties which are not under the control of monopolistic consumers. This has been brought about by the increasing demand for bauxite. It is the result not only of the expansion of the aluminium industry but of the use of bauxite for the purification of petroleum and other oils; a new field has opened with the successful manufacture of so-called bauxite (high-alumina) cements. (See '*The Mining Journal*' of 30th December, 1922.)

Aluminium reduction companies will seldom accept bauxite with more than 5 per cent. silica although they have been known to take delivery of ore with as much as 20 per cent. ferric oxide. Chemical wrks do not refuse bauxite containing 10 per cent. of silica if the a mina content is high and the ferric oxide percentage is below 3 per cent. They seldom accept ore with more than 5 per cent. ferric oxide. Manufacturers of abrasives while demanding the best grades of normal bauxite often utilise ore with less than 50 per cent. alumina and more than 10 per cent. silica or 15 per cent. ferric oxide. Makers of furnace refractories stipulate that the ferric oxide content must be low but may accept bauxite with as much as 25 per cent. silica. In some cases they prefer to use a material so rich in silica that it can scarcely be called a bauxite. Investigators in oil refineries do not yet know, with any exactness, the type of bauxite most suited to their use. Certain normal Indian ores have been found to de-sulphurise and decolorise petroleum very effectively but have not been equally efficient with petrol or heavy oils. The purification of petroleum and other oils is evidently effected by the colloidal properties of the bauxite rather than by chemical action; in consequence of this it is at present impossible to judge the value of a bauxite for this purpose on its chemical composition alone. Experiments in the production of high-alumina cements ('*ciment fondu*', etc.), although showing the commercial importance of the finished product have not yet proved that one type of ore is more particularly desirable than another provided the alumina content is high.

All consumers would probably be willing to accept somewhat inferior qualities of ore at advantageous prices if the composition of the material could be guaranteed within certain agreed narrow

limits. It is the practice of most consumers partially to calcine the raw bauxite before finally grinding it to dust or slime. This calcination, usually performed at a temperature not exceeding 400° C., drives off a considerable amount of the combined water, and gets rid of any organic matter which may be present. It also converts ferrous oxide into the more manageable ferric oxide. The alumina content is naturally increased by this calcination, but it is not to be forgotten that the percentage of the impurities is also raised. Raw bauxite is notoriously variable in composition, and in large occurrences it is advisable to sample and analyse the deposit very thoroughly. It is possible, by mixing known qualities of bauxite from various parts of a single large deposit, or from more than one deposit, to maintain shipments of uniform quality. In this way, if due attention were paid to the sampling and chemical analysis of bauxite, it is probable that considerable quantities of low grade ore could be mixed with particularly rich material.

Memoirs Geological Survey of India, Vol. XLIX, part I, (1923), gives details of the several Indian occurrences of bauxite. The localities in which efforts have been made to work bauxite in India are :—Katni in the Jubbulpore district of the Central Provinces, Belgaum in the Belgaum district and Kapadvanj near Khaira in Gujerat of the Bombay Presidency. Among other areas which have been carefully examined and in which good bauxite is known to occur may be mentioned the following :—Chakar in Jammu, Kashmir; Rupjar in Balaghat, Central Provinces; Radhanagri in Kolhapur State, Bombay Presidency; South Rewah; and Pakripat in the Ranchi district of Bihar and Orissa.

Indian occurrences of bauxite.

At the present time active mining, but on a small scale, is in progress only at Katni and Kapadvanj. In the former case the bauxite is chiefly used in the manufacture of aluminous sulphates in India, whereas the bauxite of Kapadvanj appears to be entirely absorbed for the purification of kerosene.

A general summary of the Indian occurrences of bauxite and its mode of origin by the writer was published in *The Mining Magazine* of February, 1922. A similar statement with regard to the aluminium industry as a whole appeared in *The Mining Journal* issues of the 28th October, and 4th November, 1922. See also 'Bauxite' by Cyril S. Fox, 1927, and 'The Industrial Uses of Bauxite' by N. V. S. Knibbs, 1928.

Bismuth.

[E. H. PASCOE.]

The only part of the Indian Empire where bismuth ores have been extracted– and then only on a very small commercial scale– is the Tenasserim division of Lower Burma. Native bismuth and the sulphide, bismuthinite, occur in the wolfram and cassiterite-bearing veins of certain localities in the Tavoy district, and also in the adjoining districts of Mergui and Amherst.

Dr. Coggin Brown states[1]: 'the quantity of the bismuth minerals found in the veins is in itself too insignificant to permit of their profitable extraction on this account alone, and the insignificant amount of bismuth which has been exported from Burma up to the present time has been recovered as a by-product in the sluicing of eluvial deposits for wolfram and tin-stone. As the veins are broken down under the general action of denudation they shed their metallic contents into the surface soil. Deposits formed in this manner on the hill sides are often profitable to work on account of their metallic contents. The bismuth minerals are either hand-picked out of the clean concentrates after sluicing operations, or recovered chemically from the tin ore after magnetic separation. The chemical process is not carried out in India, but is known to have been performed on certain Tavoyan tin ores after their arrival in the United Kingdom. For this reason the total amount of the small quantity of bismuth ore produced in recent years in Burma is not known, and the only recorded figures are 5 cwt. of ore valued at £163, shipped separately as such. The future output of bismuth ores from India depends entirely on their separation as by-products in the wolfram and tin-ore mining industry of Lower Burma. No deposits have as yet been discovered rich enough to exploit for their bismuth contents alone; on the other hand it is certain that small amounts of bismuth minerals are wasted because of the prevalent ignorance of their properties and value. But even when this is allowed for, it must be admitted that the quantities probably obtainable from known deposits in the Tavoy and Mergui districts are comparatively insignificant.'

The production in the Tavoy district amounted to 80 lbs. valued at Rs. 240 in 1924, 48 lbs. valued at Rs. 128 in 1927, and 82 lbs. valued at Rs. 267 in 1928.

[1] *Bull. Ind. Industries and Labour*, No. 6, pp. 23, 24, 28.

Borax.

[E. H. Pascoe.]

No undoubted occurrence of borax is known within British Indian territory, and the material exported, which during the last five years has averaged annually 2,107 cwts., of a value of Rs. 52,320 (Table 114), is practically all obtained from Tibet and Ladakh, being imported across the frontier into the Punjab and United Provinces; the quantity from Ladakh is very small, the reported total for the whole five years not exceeding 40 cwts. The word *tincal*, by which it is known in the bazars, is in common use on the Punjab frontier in the Himalayan passes, where can be seen herds of goats and sheep coming down in the spring from Tibet, each carrying two small bags of borax or salt to be bartered for Indian and foreign stores.

Table 114.—*Exports of Borax by sea from India during the years 1924-25 to 1928-29.*

——	Quantity.		*Value.*	Value per cwt.
	Cwts.	Metric Tons.	*Rs.*	Rs.
1924-25	3,713	189	*1,00,288*	27·01
1925-26	2,266	115	*49,068*	21·65
1926-27	1,782	90	*44,205*	24·81
1927-28	1,256	64	*35,351*	28·15
1928-29	1,520	77	*32,683*	21·50
Average .	2,107	107	*52,320*	24·83

In addition to the borax sent by sea to foreign countries, small quantities cross the frontier into Nepal, Kashmir, Kelat, Afghanistan, Tibet and China. Of late years the export trade in borax has very seriously declined. Forty-five years ago the quantity sent out of India amounted to over 16,000 cwts. a year, valued at £24,000. At that time the greater part of the material exported went to the United Kingdom (14,134 cwts. in 1883-84), but, with the dis-

covery of large deposits of calcium borate in America, the demand for borax from India ceased, and, under normal conditions, the only large customers are now the Straits Settlements and China (Hongkong).

The annual amount of borax imported into India across the frontier averaged 22,969 cwts. of the value of Rs. 5,70,520 for the period of the preceding review. Owing to the discontinuation of the old system of registration of trade by land since 1st April, 1925, figures for the imports of borax by land are no longer available. The annual amount imported by sea during the past five years has averaged (as shown in Table 115) 13,947 cwts. of the value of Rs. 2,36,248 as compared with 8,766 cwts. of the value of Rs. 2,52,703 during the period 1919-20 to 1923-24.

TABLE 115.—*Imports of Borax by sea during the years 1924-25 to 1928-29.*

—	Quantity.	*Value.*	Value per cwt.
	Cwts.	*Rs.*	Rs.
1924-25	9,564	*2,18,209*	22·82
1925-26	10,525	*2,14,572*	20·39
1926-27	11,307	*1,99,416*	17·64
1927-28	16,834	*2,64,599*	15·72
1928-29	21,503	*2,84,445*	13·23
Average .	*13,947*	*2,36,248*	16·94

The borax obtained in the Puga valley of Ladakh, Kashmir, is deposited from hot springs associated with sulphur deposits, which probably represent the final phase of declining volcanic action. The material collected in Tibet is obtained from salt lakes, which have

possibly obtained their borax in a similar way from hypogene sources. In other parts of the world, as in California, Argentina, Bolivia, and Chile, deposits of calcium borate, colemanite, are worked for their boracic acid, besides the borax of salt lakes and marsh deposits. In Italy borax is obtained from volcanic fumaroles.

Building Materials.

[E. H. PASCOE.]

As remarked by Sir Thomas Holland, 'if the extent of the use of building materials could be expressed by any recognised standard, it would form one of the best guides to the industrial development of a country. The attempt made to obtain returns of building stones, road metal, and clays used in India was abandoned when it was shown, in 1899, that the returns could not possibly rank in value much above mere guesses'.

In the absence of statistics, it is difficult to express shortly the trade in a material so widespread as common building stone. There are, however, a few features which are specially developed in, if not peculiar to, India. In the southern part of the Peninsula, various igneous rocks--the charnockite series near Madras, and the gneissose granites of North Arcot and Mysore—are largely used; in the centre, slates and limestones from the Cuddapah series, and basalt from the Deccan trap-flows are quarried. In Central India, the Central Provinces and the United Provinces, the great Vindhyan system provides incomparable sandstones and limestones, while in Bengal and the Central Provinces the Gondwana sandstones are used on and near the coalfields. In the Narbada valley the so-called coralline limestone of the Bagh series forms an excellent building stone with a certain claim to inclusion in the ornamental class. Among the younger rocks the nummulitic limestones in the north-west and in Assam are largely quarried, while the foraminiferal Porbandar stone in Kathiawar[1] is extensively used in Bombay and Karachi.

[1] A 'Memoir on the Economic Geology of Navanagar State' by G. E. Howard Adye (1914), deals with the economic uses of the miliolite limestones, Deccan Trap rocks, both acid and basic, and the laterite of this State.

The abundant development of concretionary carbonate of lime in the great alluvial plains, and the extensive development of laterite on the Peninsula and in Burma are dependent, in their more pronounced forms, on conditions peculiar to tropical climates, and these two substances, the so-called *kankar* and laterite, are about the most valuable assets in building material possessed by the country.

Imports.

The three great physical divisions of India, being the result of three distinct geological histories, show general contrasts in the materials available for simple as well as ornamental building purposes. In the great alluvial plains buildings of importance are usually made of brick, but the surrounding tracts furnish a supply of stone, which is steadily increasing with improved facilities for transport. The monotonous line of brick and stucco buildings in Calcutta has been relieved by the introduction of Vindhyan sandstones from Mirzapur and the calcareous freestones and buff traps brought from the western coast. But the use of Italian marbles, mainly for floorings and, in a smaller way, the introduction of polished granite columns and blocks from Aberdeen and Peterhead, have continued, mainly because these materials, which are no better than, and possibly on the whole inferior to, those of Indian origin, are placed on the market at cheap rates and in a manner suitable to the immediate requirements of the builder and architect. The distance of much of the Indian marble, especially the higher grade material, from the sea-board precludes cheap transport and prevents the Indian stone from competing in foreign markets with material from elsewhere. With regard to immediately local demand, however, this comparative inaccessibility protects indigenous supplies, and these are able to undersell foreign marble the transportation of which includes a considerable land journey.

During the years 1923-24 to 1927-28 the value of building and engineering materials imported from foreign countries into India has had an average annual value of Rs. 1,22,78,560, exclusive of stone and marble, which have averaged Rs. 7,40,221 annually during the same period. The substances included in the trade statistics under the heading of building materials and entered into the above total comprise asphalt, bricks and tiles, cement, chalk and lime, clay and earthenware piping. The values of some of these are given in the section on clays. The quantity of cement imported

annually, during the years 1923-24 to 1927-28 has averaged 110,235 tons valued at Rs. 66,17,151, and the annual imports of chalk and lime during the same period have averaged 1,638 tons valued at Rs. 67,338.

Ornamental building stone.

As Sir Thomas Holland has remarked,[1] 'it is naturally surprising to find that a country, which owes its reputation for architectural monuments as much to the fact that it possesses an unlimited supply of ornamental building stones as to the genius of its people, is dependent on foreign supplies to the extent indicated by these import returns. It can hardly be an accident that each dynasty which has existed in India since the wonderful Buddhist topes of Sanchi and Bharhut were erected, has been marked by the erection of great monuments in stone, and there can be little doubt that the abundance of suitable material has been an important contributory cause in the growth of India's reputation for architecture'.

Besides the architectural remains left by the Buddhists, there are famous works in stone by the Hindus of the eighth to tenth centuries, including the great Dravidian temples of Southern India, mostly built of granites and other crystalline rocks, and the richly ornamented buildings of Orissa and of Chanda built of Gondwana sandstones. The Pathans and Moghals utilised both the Vindhyan sandstones of Central India and the beds of marble in Rajputana for building their magnificent mosques, palaces and tombs in the cities of Northern India. It is only necessary to mention here Akbar's city of Fatehpur Sikri, where the red and mottled sandstone of the Bhander series was used, and the famous Taj, built mainly of white Mekrana marble, with elaborate inlaid work of yellow marble and shelly limestone from Jaisalmer, onyx marble from the Salt Range, black calcareous shales from the Vindhyans of Chitor, malachite from Jaipur, carnelians and blood-stones from the Deccan trap, and red jasper from the Gwalior (Bijawar) series.

The delicate and intricate carvings, for which some varieties of the Indian sandstones are so well suited, are admirably shown in an 'Illustrated Catalogue of Ornamental Carved Stone in Gwalior,' published by the Department of Commerce and Industry, Gwalior, in 1912.

[1] *Rec. Geol. Surv. Ind.*, XXXII, p. 103 (1905).

Although, in most cases, reliable statistics concerning the production of building stones in India are not obtainable, yet we give here such figures as are available, excluding those relating to marble and slate, which are treated in separate sections.

Granite and gneiss.

Gneissose granites and gneisses are used as building stones and for road-metal in many parts of peninsular India, particularly in the Madras Presidency, for which returns have been available since 1910. Figures of production and value for Bihar and Orissa, Burma, and Madras are given in Table 116.

From 1907 to 1908 there was a sudden increase in the Burmese production of granite and gneiss, from 27,781 tons to 340,939 tons. This was largely due to the development of quarries in gneissose granite in the Thaton district for the supply of stone to the Burma Railways Company and the Town Lands Reclamation Works in Rangoon. Owing probably to the same causes the production of the Thaton quarries is reported to have reached the enormous figure of 7,642,268 tons in 1909, valued at £344,704.[1] Since then the production from this district has been relatively small, but in 1909, quarrying began at Kalagauk Island in the Amherst district in connection with the Rangoon River Training scheme. The output in 1909, was 57,500 tons and with the introduction of a regular service of hopper barges, reached a total of 295,125 tons in 1912. With the completion of the scheme the works were closed down in 1914. From 1914, there was a steady rise up to 1917, and a somewhat sharp fall of 72,000 tons in 1918, from Burma. During the five years 1919-23 there was a still further fall, the annual average amounts working out to less than 116,000 tons; during the quinquennium under review this figure rose to nearly 638,000 tons, the annual average being 525,980 tons. The figures for Madras are as capricious in their fluctuation as they were in the preceding period, but are again much smaller; the average annual output has in fact been scarcely more than one-half of that during 1919-23. Too much significance must not be placed on these figures, which are probably largely affected by the periodical demand for road-metal for the town of Madras.

[1] The Government of Burma were unable to confirm this figure owing to the destruction of the district records.

TABLE 116.—*Production of Granite and Gneiss during the years 1924 to 1928.*

—	1924		1925		1926		1927		1928		AVERAGE.	
	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*
	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*
Assam . .	2,225	*4,944*	13,473	*29,623*	2,924	*6,346*	4,616	*17,240*	26,145	*47,397*	9,877	*21,110*
Bengal . .	..	..	..	..	90,000	*1,80,000*	134,125	*1,65,153*	94,629	*70,533*	(*a*)106,251	(*a*)*1,38,562*
Bihar and Orissa.	274	*479*	7,162	*9,308*	20,731	*41,206*	356,361	*4,18,447*	283,181	*3,89,165*	133,542	*1,71,721*
Burma . .	412,429	*10,93,831*	496,136	*9,75,253*	460,591	*10,92,439*	622,756	*12,29,978*	637,990	*18,08,440*	525,980	*12,39,988*
Central Provinces.	..	..	..	..	..	..	..	..	90	*470*	..	..
Madras . .	7,065	*1,435*	8,211	*1,613*	14,040	*8,776*	16,055	*8,981*	72,323	*7,597*	11,589	*5,680*
TOTAL .	**421,993**	*11,00,689*	**524,982**	*10,15,797*	**588,286**	*13,28,767*	**1,133,913**	*18,39,799*	**1,054,358**	*23,23,602*	**787,139**	*15,77,061*
Total value in sterling.		*£79,186* (£1 = Rs. 13·9)		*£76,375* (£1 = Rs. 13·3)		*£99,162* (£1 = Rs. 13·4)		*£137,298* (£1 = Rs. 13·4)		*£173,403* (£1 = Rs. 13·4)		£113,085

(*a*) Average of three years.

Sandstone.

The available figures for the production of sandstone in India are shown in Table 117. Those shown for the United Provinces refer to the output of Vindhyan sandstone from the Allahabad and Banda districts. The figures for Bihar and Orissa refer chiefly to the output of Vindhyan and Gondwana sandstones, from the districts of Shahabad and Manbhum, respectively. A quartzite of good quality from Susunia Hill, Bankura, has been largely employed in Calcutta for paving and curb stones. In Burma, sandstone is quarried in many districts, amongst which may be mentioned the Northern Shan States, Meiktila, Thaton, Minbu, Myingyan, Sagaing, Sandoway and Akyab. The largest producer of sandstone between 1924 and 1928 was, however, Rajputana, the annual output averaging a little under 159,000 tons; most of the stone was contributed by Alwar, Jodhpur, Bikaner and Dholpur States.

Limestone.

The subject of building materials naturally includes limestone and dolomite used as a building stone, and the two derived products, lime and cement. Limestone is also used as a flux in the smelting of iron ore. In the present review cement is dealt with under a separate heading. Lime and cement are obtained, naturally, from the most conveniently situated deposits of limestones, such as those of the Upper Vindhyan series worked near Sutna in the Rewah State by the Sutna Stone and Lime Company, Ltd.; those of the Lower Vindhyan series worked at Katni in the Jubbulpore district by Messrs. Cook & Sons and others; those worked in the Cuddapah series at Bisra and Rourkela in Gangpur State by the Bisra Stone Lime Company, the material being mostly used as a flux in the iron and steel industry; or the various bands of crystalline limestones in Madras, Central India, and Rajputana, and the nummulitic limestones of Assam. The last-mentioned stone is brought down by boat during the Rains from the southern scarp of the Khasi and Jaintia hills to Sylhet where it is burnt in primitive kilns; Calcutta at one time derived its main supply of building lime from this source. Vast quantities of limestone, suitable for building-stone or for lime-burning, are available over large areas of Baluchistan. Such figures as are available for the production of limestone during the period under review are given in Table 118.

The production of the Sutna Stone and Lime Company in Rewah may be gauged from the quantities despatched from the works, and has fallen to less than half what it was during the post-War quin-

TABLE 117.—*Production of Sandstone during the years 1924 to 1928.*

—	1924		1925		1926		1927		1928		AVERAGE.	
	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*
	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*
Assam . .	..	..	..	..	7,460	*21,567*	.	..	6,168	*14,559*	(*a*)6,814	(*a*)*18,063*
Bihar and Orissa.	149,965	*32,336*	9,949	*9,738*	29,929	*30,142*	18,583	*20,752*	26,337	*32,550*	46,953	*25,104*
Bombay .	4,800	*8,100*	7,750	*13,000*	7,500	*13,000*	6,500	*11,000*	8,366	*11,800*	6,983	*11,380*
Burma . .	140,671	*1,36,131*	81,209	*1,36,704*	71,425	*1,23,860*	110,817	*1,45,807*	126,945	*1,81,760*	106 213	*1,44 852*
Central India .	..	..	..	..	..	..	3,714	*30,200*	6,246	*50,776*	(*a*)4,980	(*a*)*40,488*
Central Provinces.	..	..	4,668	*17,581*	..	..	538	*732*	..	..	(*a*)2,603	(*a*) *9 156*
Gwalior .	19,265	*62,539*	18,127	*54,577*	16,688	*55,632*	13,824	*43,870*	11,808	*12,692*	15,942	*51,862*
Mysore . .	..	..	..	..	..	..	..	..	1,364	*8,890*	..	..
Rajputana .	131,036	*7,88,832*	192,176	*9,20,985*	196,706	*7,07,096*	168,269	*5,20,896*	105 996	*5,72,494*	158 887	*7,02,061*
United Provinces.	..	..	10,700	*40,415*	9,502	*34,163*	28,808	*28,654*	56,349	*53,906*	(*b*)26,338	(*b*) *59,285*
TOTAL .	**445,737**	*10,27,938*	**324,579**	*11,93,000*	**339,210**	*9,85,460*	**351,648**	*8,01,911*	**349,573**	*9,69,429*	**375,633**	*10,42,251*
Total value in sterling.		*£73,952* (£1 = Rs. 13·9)		*£89,699* (£1 = Rs. 13·3)		*£73,542* (£1 = Rs. 13·4)		*£59,844* (£1 = Rs. 13·4)		*£72,345* (£1 = Rs. 13·4)		*£72,876*

(*a*) Average of two years.
(*b*) Average of four years.

TABLE 118.—*Production of Limestone and Kankar during the years 1924 to 1928.*

—	1924		1925		1926		1927		1928		AVERAGE.	
	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*
	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons	*Rs.*	Tons.	*Rs.*
Assam . .	93,430	*2,05,537*	75,550	*1,52,211*	63,325	*1,45,178*	69,476	*1,13,629*	66,700	*1,05.311*	73,696	*1,44,373*
Baluchistan .	2	*200*	2	*180*	2	*180*	2	*180*	..	..	2	*148*
Bihar and Orissa.	705,707 (*a*)	*20,94.859*	921.981 (*b*)	*21,69,161*	802.601 (*c*)	*17.89,197*	1,026,663 (*d*)	*20,93,764*	805,865 (*e*)	*17,12,623*	852,563	*19,71,921*
Burma . .	316,638	*4,10,183*	219,525	*3,08,829*	187,130	*3,68,507*	324,042	*5,75,852*	215,753	*3,63,604*	252.618	*4,05,395*
Central India .	122,453	*68,336*	93,875	*86,184*	70,980	*62.656*	128.577	*96,024*	113,705	*72,749*	105.918	*77,190*
Central Provinces.	333,425	*6,29,482*	361,062	*5,79,315*	353.406	*5,33,866*	474,348	*6,97,150*	673,627	*9,06,737*	439,173	*6,69,310*
Kashmir .	15,878	*10,000*	159	*4,500*	..	..	..	..	..	..	3,207	*2,900*
Madras . .	13,271	*13,443*	13,996	*16,519*	12,628	*22,774*	13,518	*13,668*	16,180	15,436	13,919	16,368
Mysore . .	56,754	*16,374*	10,073	*31,422*	6,468	*18,108*	3,399	*6,170*	3,228	*4,098*	15,984	*15,234*
N.-W. F. Province.	2,416	*1,957*	2,841	*2,684*	1,682	*1,237*	2,073	*1,959*	11,037	*8,112*	4,010	*3,190*
Punjab . .	18,742	*16,835*	48,247	*61,745*	760,031	*10,00,888*	454,669	*5,95,016*	494,434	*7,73,228*	355,225	*4,89,542*
Rajputana .	129,710	*1,68,714*	160,033	*2.19,827*	157,583	*1,92,176*	192,807	*2,45,985*	200,946	*3,25,960*	168,216	*2,30,533*
United Provinces.	961,352	*12,05,967*	1,208,509	*14,63,928*	679,742	*9,73,351*	559,804	*7,24,685*	580,724	*7,16,798*	798,026	*10,16,945*
TOTAL .	2,769,778	*48,41,887*	3,115,853	*50,96,505*	3,075,578	*51,08,118*	3,249,378	*51,64,082*	3,182,199	*50,04.656*	3,082,557	*50,43,049*
Total value in sterling.		*£348,337* (£1 = Rs. 13·9)		*£383,196* (£1 = Rs. 13·3)		*£381,203* (£1 = Rs. 13·4)		*£385,379* (£1 = Rs. 13·4)		*£373.482* (£1 = Rs. 13·4)		*£374,319*

(*a*) Includes 300,553 tons of dolomite. (*b*) Includes 316,580 tons of dolomite. (*c*) Includes 135,424 tons of dolomite. (*d*) Includes 59,679 tons of dolomite. (*e*) Includes 17,990 tons of dolomite.

quennium. During the five years 1924-28 the quantity of limestone has averaged annually 20,086 tons valued at Rs. 23,351. During the period under review unslaked lime manufactured by this company averaged 12,529 tons valued at Rs. 1,61,345, and slaked lime 638 tons valued at Rs. 2,569; both show a marked decrease. As is shown by these figures, much of the limestone quarried is not converted to lime, but is instead railed a distance of 530 miles to the Barakar Iron Works, where it is used as a flux in the blast furnaces.

Besides the Maihar Stone and Lime Company, three other companies, *viz.*, the Mahadeo Stone and Lime Company, the Imperial Stone Lime Manufacturing Company and the Jagjahir Stone and Lime Company, are at present working for limestone in the Maihar state. The annual output from that state showed an increase to more than three times what it was in the previous five years, and averaged 85,477 tons valued at Rs. 53,482.

The production from Bihar and Orissa is derived chiefly from Gangpur State with, in some years, large amounts of *kankar* and limestone from the Shahabad district. The Gangpur output includes the production of the Bisra Stone Lime Company, of B. P. Byramji and Company and of the Tata Iron and Steel Company. The average annual production of the Bisra Stone and Lime Company was 355,412 tons of limestone valued at Rs. 5,93,847, and 23,972 tons of dolomite valued at Rs. 39,337—a notable increase when compared with the production of the previous quinquennium. The Tata Iron and Steel Company produced annually an average of 67,839 tons of limestone valued at Rs. 2,25,342 and 110,542 tons of dolomite at Rs. 3,46,534. The company are at present using limestone as a flux in preference to dolomite. The percentage of insoluble matter in their limestone deposits, however, increased so much at depth that the material was found unsuitable as a flux for blast furnace purposes. The company have, therefore, closed down their limestone quarries, and are at present obtaining their requirements from the Bisra Stone and Lime Company. The following table shows the production of limestone and dolomite by the Tata Iron and Steel Company:—

——	Limestone.	Dolomite.
	Tons.	Tons.
1924	44,509	258,313
1925	72,285	220,802
1926	91,554	64,359
1927	103,475	9,235
1928	27,372	*nil*

Towards the end of the quinquennium 1909-13 the opening of the Dehri Rohtas Light Railway led to the formation of three companies—the Kalianpur Lime Works, Limited, the Kuchwar Lime and Stone Company, Limited, and the Sone Stone and Lime Works—to work the Rohtas (Vindhyan) limestone at and near Banjari in the Shahabad district. These are still the three principal companies at work, but more than a dozen others are at present quarrying limestone in this district. The total output of limestone in the Shahabad district, in which most of the workings have now come under the Indian Mines Act, averaged 258,654 tons valued at Rs. 6,68,540.

The production shown for the Central Provinces is derived mostly from Katni, where the limestone quarries come under the control of the Indian Mines Act. The quantity raised under this Act averaged 366,288 tons worth Rs. 5,05,149, compared with 171,416 tons valued at Rs. 2,95,979 for the previous quinquennium. The average daily labour employed is shown below separately for each year, the annual average for the period being 4,476 persons—a figure only 19 short of that for the previous five-year period.

Production of Limestone from Katni Act-Mines and Labour Statistics.

——	Quantity.	*Value.*	Persons employed daily.
	Tons.	*Rs.*	
1924	259,039	*4,46,665*	5,255
1925	329,167	*5,11,793*	3,781
1926	305,168	*4,29,462*	4,411
1927	356,696	*4,37,732*	3,894
1928	581,372	*7,00,092*	5,042
Average	*366,288*	*5,05,149*	4,476

A very small proportion of the limestone, shown as quarried in Assam, comes from the Lakhimpur district and Manipur, practically the whole of the output being from the Khasi and Jaintia hills, where the nummulitic limestone is being worked by the Sylhet

Lime Company, Limited. The average output from this province amounted to 73,696 tons valued at Rs. 1,44,373 annually.

As regards the other areas reported as producing limestone, the limestone of Burma comes from many localities, the most important of which are the Amherst, Mandalay, Meiktila, Sagaing and Lower Chindwin districts, and the Northern Shan States. From Madras production is reported in small quantities in several districts, of which North Arcot and Tinnevelly are worth mentioning. The production reported from the Punjab comes mainly from the Attock, Jhelum and Rawalpindi districts, whilst the output reported from Rajputana comes chiefly from various States of which Bundi, Jodhpur and Sirohi are the most important. The apparent increase in the total production from the United Provinces is due to the inclusion of *kankar* which is used mostly for the metalling of roads instead of in the manufacture of lime. The production of *kankar* averaged 775,846 tons annually; of this only 4,271 tons were used in the manufacture of lime, the rest having been employed as road-metal. The output of limestone in the United Provinces averaged 22,180 tons, the more important districts being Dehra Dun, Etawah and Naini Tal.

Kankar.

One of the most widespread and interesting sources of lime is the material generally known by the name of *kankar*, some of the more solid varieties of which have found a limited use as building-stone. The commonest mode of occurrence is in the great alluvial deposits, particularly in the older alluvium, in which the calcareous substances have segregated from the rest of the materials and have grown into irregular lumps like flints in chalk, including in the concretions a certain amount of the argillaceous substances which, when the *kankar* is burnt, is present in a proportion not far removed from that necessary to produce a hydraulic lime. The material of these concretions constitutes, in fact, a 'natural cement'.

Another industry for which a high grade limestone is required is the manufacture of calcium carbide and calcium cyanamide. The latter is becoming increasingly important as a nitrogenous manure and a greater supply would in all probability create its own demand.

Laterite.

Laterite is widely distributed over the whole of the Peninsula of India and in Burma. In certain cases it has a special value as an ore of aluminium (see page 331), iron or manganese, according to composition (see

TABLE 119.—*Production of Laterite during the years 1924 to 1928.*

—	1924		1925		1926		1927		1928		AVERAGE.	
	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*
	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*
Assam . .	14,713	*40,483*	6,362	*13,136*	12,112	*31,601*	17,478	*29,985*	22,173	*33,005*	14,568	*29,642*
Bihar and Orissa.	13,205	*463*	1,874	*581*	1,474	*516*	1,835	*603*	3,184	*776*	4,314	*588*
Bombay .	376	*293*	4,700	*10,550*	1,550	*3,760*	1,400	*3,300*	2,520	*5,265*	2,109	*4,633*
Burma . .	589,702	*5,78,748*	177,707	*2,68,065*	130,188	*2,76,908*	262,035	*4,01,633*	282,190	*4,98,866*	288,364	*4,04,844*
Central Provinces.	..	..	..	..	..	..	..	..	681	*596*	..	..
Madras . .	75,525	*64,090*	93,331	*49,872*	157,828	*97,683*	94,386	*62,684*	87,585	*81,715*	101,731	*75,209*
Mysore . .	..	..	..	..	80	(*a*)	720	*9,000*	1,593	*2,684*	(*b*) 798	(*b*) *3,895*
TOTAL	693,521	*6,84,077*	283,[illegible]74	*3,42,204*	303,232	*4,10,468*	377,854	*5,27,205*	399,926	*6,22,907*	411,884	*5,18,811*
Total value in sterling.		*£49,214* (£1 = Rs. 13·9)		*£25,730* (£1 = Rs. 13·3)		*£30,632* (£1 = Rs. 13·4)		*£39,344* (£1 = Rs. 13·4)		*£46,486* (£1 = Rs. 13·4)		*£38,281*

(*a*) Not available. (*b*) Average for three years.

page 232), but it is also very widely used as road-metal and as a building stone for culverts and buildings; for the latter purpose it possesses one advantage over other stones in the ease with which it can be cut into blocks and its power of subsequently hardening when exposed to the air. In most cases, no statistics are collected. In Table 119 are given the statistics as far as available. The figures for Assam relate to Cachar and Sylhet and in some years to the Kamrup district, while those for Bihar and Orissa refer to the Puri district and the Nilgiri state. The annual Burmese output averaged 288,364 tons valued at Rs. 4,04,844. The output comes from some eighteen districts, but the most important are Amherst with an average annual output during the period of 55,887 tons, Hanthawaddy with 14,187 tons, Insein with 38,933 tons and Thaton with 125,308 tons. The laterite of Madras comes from the Trichinopoly, Malabar and Chingleput districts, the last two contributing annually on an average 45,532 tons and 42,494 tons, respectively.

Gravel.

The mineral returns of Burma regularly give details of the production of gravel in various districts; the total figures are :—

			Rs.
1924	136,344	tons valued at	74,870
1925	154,171	,, ,, ,,	69,472
1926	132,511	,, ,, ,,	53,064
1927	216,045	,, ,, ,,	64,354
1928	259,092	,, ,, ,,	1,24,166
Average	*179,632*	,, ,, ,,	*77,185*

The most important districts are Mergui, Pakokku, Mandalay, Shwebo, Sagaing and the Northern and Southern Shan States. The material is used for the repair of roads.

A hard conglomerate, occurring below the Mergui series, is being quarried in Pataw Island opposite the town of Mergui, and used in the harbour construction work along the margin of the town.

Cement.

[A. M. Heron.]

For about ten years previous to the War, cement had been manufactured from sea-shells by The South India Industrials, Limited,

Washermanpet, Madras, but the output was on a small scale and never exceeded 5,000 tons per annum. The Portland Cement industry may be said to have started in India at the end of 1914, when the Indian Cement Company (Tata Sons, Limited), opened their works at Porbandar in Kathiawar. During the War two other companies commenced production, the Katni Cement and Industrial Company, at Katni, Central Provinces (Macdonald and Company) and the Bundi Portland Cement Company (Killick, Nixon and Company), at Lakheri, Bundi State. The bulk of the output of these three factories was taken by Government, and as the importation of foreign cement was largely interrupted during the War, their production increased substantially, being 73,728 tons in 1917, 84,344 tons in 1918, and 86,812 tons in 1919. The post-War industrial activity in 1919 and 1920, increased the demand for cement, and very high prices prevailed, with the result that the existing companies added largely to their plants, and new companies were formed. During the quinquennium 1919-23, the following companies came into operation:—

Dwarka Cement Company, Limited, Dwarka, Kathiawar, now called the Okha Cement Company, Limited.

Sone Valley Portland Cement Company, Limited, Japla, near Daltonganj (Martin and Company).

*Jubbulpore Portland Cement Company, Limited, Mehgaon, near Jukehi, C. P., 10 miles from Katni.

Gwalior Portland Cement Company, Limited. (Gwalior State Trust, Limited), Banmor, G. I. P. Railway, 12 miles north of Gwalior City.

Punjab Portland Cement Company, Limited (Killick, Nixon and Company), Wah, near Hasan Abdal, Attock district.

Central Provinces Portland Cement Company, Limited Kymore, near Jukehi, C. P., 10 miles from Katni. (Messrs. Dinshaw and Company, Bombay.)

During the quinquennium under review, 1924-28, the following company, amongst others, has been started:—

Shahabad Cement Company, Limited (Tata Sons, Limited), Shahabad, Hyderabad State.

* Now the United Cement Company of India, Limited, under the same management as the Central Provinces Portland Cement Company, Limited.

The statistics of import and production show how the industry has increased.

TABLE 120.—*Indian production and imports of Portland Cement.*

Year.	Indian Production.	Imports.
	Tons.	Tons.
1920	91,253	155,480
1921	132,812	127,565
1922	151,336	146,313
1923	234,936	124,886
1924	263,746	124,286
1925	360,549	129,198
1926	375,993	99,967
1927	477,640	127,662
1928	558,544	135,574

The excellent quality of the Indian product has overcome the initial prejudice against an untried article, and the industry is now firmly established. In common with others, it passed through a time of depression and over-production at the beginning of this quinquennium, and an application for protection was made to Government, by several of the companies. There is an import duty of Rs. 9 per ton on Portland cement (excluding white Portland cement) and of 15 per cent. *ad valorem* on cement (excluding Portland cement other than white Portland cement).

During recent years new uses for concrete, not only in heavy constructional work, but in ornamental details, frames and mouldings of buildings, reinforced bridges, modern arterial roads, pipes and even the linings of canals, have vastly widened the demand for cement, and with the steady expansion of industrial activity increasing consumption in its everyday uses, the cement industry in India may look to a prosperous future.

The Concrete Association of India,[1] under the auspices of the Indian Cement Manufacturers Association, established in 1927, helps in developing the industry by giving free advice and assistance in the uses of cement, and issues a monthly magazine and pamphlets in

[1] The author is greatly indebted to Mr. T. Campbell Gray of this association, for much information.

English and vernacular languages dealing with the correct preparation of concrete and its uses in ordinary works.

Portland cement is usually produced by the action of intense heat on a finely ground mixture of limestone or marl with clay or shale. It can be produced from raw materials differing greatly in composition, texture, etc., but the mixture should contain about 75 per cent. of calcium carbonate and 25 per cent. of clay material, with a little gypsum.

The calcium in most limestones is partly replaced by magnesium, but, for Portland cement, the amount should not be more than 3 to 4 per cent. of magnesium carbonate. It has been described as 'a compound consisting chiefly of silicates and aluminates of lime, produced by the calcination to incipient vitrification of a mechanical mixture of chalk and clay, or similar materials containing the requisite chemical constituents, the clinker thus produced being subsequently ground to a more or less impalpable powder'.[2] Occasionally an argillaceous or clayey limestone occurs in which the essential constituents of cement are present in almost the correct proportions, as in the case of *kankar* (*q. v.*). In such a case very little additional material will be required to bring the mixture to the correct composition. This, however, is unusual, and it is customary to use a mixture of limestone, which provides the calcium, and shale or clay which provides the alumina and silica. In Great Britain the chalk used is almost pure carbonate of lime ($CaCO_3$), and the required amounts of silica and alumina are introduced from the clay. The Madras Portland Cement Company, Limited, apparently obtain their calcium from shells, which are quarried in the Chingleput district. Most of the other companies use limestone.

In India some of the limestones contain all the ingredients in almost correct proportions. At Banmor (Gwalior Portland Cement Company, Limited) the limestone so nearly contains the necessary silica and alumina that the clay added is less than one per cent., and at Lakheri (Bundi Portland Cement Company, Limited) no clay at all is used, the correct proportion being obtained by mixing different grades of limestone. In other cases substantial amounts of clay have to be added. The proportion of gypsum necessary is

[2] 'Portland Cement' by D. B. Butler.

about 5 per cent., varying with the time of setting desired. The process of manufacture may be divided into three stages. In the first stage the limestone and clay are crushed, ground and mixed, as finely and intimately as possible, either dry or as a 'slurry' with water. In the second stage this mixture is calcined in a steel rotating kiln, lined with refractory bricks. The kiln is a tube, 100 to 250 feet in length, and 8 to 10 feet in diameter, inclined at a low angle to the horizontal, and rotating slowly at one or two revolutions per minute. The mixture of limestone and clay is fed into the kiln at its higher end, and descends slowly under gravitation, while powdered coal is injected at the lower end and, igniting on entry, creates an intense heat. The carbonate of lime of the limestone is decomposed by the heat, and the free lime combines with the silica and alumina of the clay. The product of calcination is called 'clinker' and passes out at the lower end of the kiln. The third stage of manufacture is the grinding of the clinker to a fine powder, and the mixing of gypsum with it. Though the process of manufacture is essentially simple, the grinding and calcining machinery is heavy and expensive, and a complicated system of mechanical conveyors is necessary to carry the materials through the plant.

Limestone of excellent quality and in abundant quantity exists in many parts of the country close to railway lines, so that the factories have usually been established near the quarries. Suitable clay is invariably to be found close to the works. Gypsum is produced in India, but has to be brought long distances, and even though the quantity of this does not exceed 5 per cent. of the output of cement, the freight on gypsum is an appreciable item, and may amount to as much as one rupee per ton of cement. Counterbalancing these natural advantages, almost all the cement factories are situated at such a distance from the coalfields that the freight on coal is a very serious item in the costs. Inferior local coal may in some instances be used for raising power in the works, but the coal used in the kilns must contain a low percentage of ash and sulphur, for 1·2 per cent. of sulphur is fixed as the maximum allowed by the British Engineering Standards Association. For this reason at least half of the coal used must be from the Bengal and Bihar coalfields. With the exception of the two concerns in Kathiawar and the small one at Madras, none are within 300 miles of a seaport. This gives Indian cement an advantage as far as up-country markets are concerned since imported cement bears

heavy freight charges to these inland centres, but on the other hand the principal regular market is in the cities of Calcutta, Bombay and Rangoon, where sea-borne cement is at a great advantage.

In the article on bauxite (pp. 338—339) attention has been drawn to the use of that substance in the manufacture of high-alumina, rapid-hardening cements (*ciment fondu* or Lafarge cement), which are resistant to sea-water and water containing sulphates. In view of the natural advantages which India possesses in large deposits of bauxite, especially at Katni, where three cement factories are operating, this branch of the industry might well repay investigation by the manufacturers.

The Indian Cement Manufacturing Companies.

Name of Company.	Date when manufacture commenced.	Site of the works.	Full capacity of plant.	Fixed capital expenditure of the company, lakhs of rupees in 1925.	Amount of raw materials for 1 ton of cement.
			Tons.		
South India Industrials, Ltd.	1904	Washermanpet, Madras.	10,000	8·8	..
Indian Cement Co., Ltd.	1914	Porbandar, Kathiawar.	30,000	27·9 (In 1928, 38 ordinary and 1 debentures issued.)	1·3141 tons limestone, 0·1102 tons siliceous stone, 0·2757 tons clay.
Katni Cement and Industrial Co., Ltd.	1915	Katni, C. P.	60,000	47·5	About 1½ tons limestone and clay (latter only a small proportion).
Bundi Portland Cement, Ltd.	1916	Lakheri, Rajputana.	65,000	48·0	1·5 tons limestone, 45 lbs. gypsum.
Dwarka Cement Co., Ltd. (now Okha Cement Co., Ltd.).	1922	Dwarka, Kathiawar.	100,000	78·0	1·25 tons limestone, 0·4 tons clay.
Sone Valley Portland Cement Co., Ltd.	1922	Japla, E. I. Ry. (Daltonganj Branch).	50,000	77·0	..

The Indian Cement Manufacturing Companies—contd.

Name of Company.	Date when manufacture commenced.	Site of the works.	Full capacity of plant.	Fixed capital expenditure of the company, lakhs of rupees in 1905.	Amount of raw materials for 1 ton of cement.
			Tons.		
Jubbulpore Portland Cement Co., Ltd. (now United Cement Co. of India, Ltd., from 1927).	1922	Mehgaon, near Jukehi, C. P., 10 miles from Katni.	60,000	56·6	About 1·6 ons of limestone and clay (latter only a small proportion).
Gwalior Cement Co., Ltd.	1923	Banmor, 12 miles from Gwalior.	40,000	41·0	1·64 tons limestone 0·0125 tons clay.
Punjab Portland Cement, Ltd.	1923	Wah, near Hasan Abdal, Punjab.	30,000	61·2	1 ton limestone, ½ ton clay, 0·05 ton gypsum.
Central Provinces Portland Cement Co., Ltd.	1923	Kymore, near Jukehi, C. P., 10 miles from Katni.	100,000	130·6	1½ tons limestone 0·45 tons clay 0·045 tons gypsum.
Shahabad Cement Co., Ltd.	1925	Shahabad, Hyderabad State.	80,000 (can be increased to 120,000).	In 1928, 50 authorised, 35 ordinary, and 12 debentures issued.	..

NOTE.—The particulars in the above table are taken chiefly from the Report of the Indian Tariff Board on the Cement Industry, 1924 and 1925.

The author is indebted to Messrs. Martin and Company, the Managing Agents of the Sone Valley Portland Cement Company, for the following account of the works and factory at Japla in the Palamau district :—

Sone Valley Portland Cement Company.

'The raw materials utilised are limestone and shale, the former being quarried on the lower slopes of the eastern escarpment of the Kymore hills at Rohtas, where the steep limestone slope rises nearly 350 feet above the level of the plain and can be most easily worked. A ropeway, five miles long, conveys the selected limestone to the

cement works, crossing the River Sone *en route*, and dropping the stone directly into the storage bin of the raw material mill in the factory standing close to the eastern bank of the river. The shale is obtained near the East Indian railway line at Daltonganj and is conveyed thence by railway to the factory, a distance of about 50 miles. The limestone having been automatically discharged from the ropeway buckets into the limestone bin passes automatically thence through two heavy crushers and thence through heavy rolls. The shale, as discharged from the railway waggons, is passed through a crusher and is elevated into a hopper whence it is fed by a revolving measuring table into the similarly measured stream of limestone passing to a great ball mill within which balls crush and mix the two materials, until the product becomes small enough to escape through the grids with which this mill is fitted. Water is admitted to the ball mill during the process and the mixture is thereby converted into a thin creamy mud technically known as 'slurry'. Passing from the ball mill, the 'slurry' enters two large revolving tube mills half filled with round flints. These machines grind the materials fine enough to leave a residue not exceeding five per cent. on a sieve having 32,400 holes per square inch. Thence the stream of slurry passes to the 'mixers' or storage basins which are equipped with rotating stirrers. The slurry is not allowed to leave the mixers until it has been sampled and found to be of correct composition. The slurry is pumped into a machine fixed above the kiln, for the purpose of regulating the feed. The kiln is a long steel tube lined with firebricks and rotating slowly on heavy steel rollers. The slurry gradually works its way towards the lower end, the water in it being driven off by the hot gases passing from the burning zone to the chimney shaft. Finely ground coal is blown in by a fan at the lower end of the kiln and there forms a great flame which fills the entire burning zone and creates a temperature ranging between 2,400° and 3,000° Fahrenheit. This raises the dried lumps of slurry to a white heat and causes a chemical combination of the lime with the silica and alumina, resulting in a clinker, in size ranging from that of a pea to that of a tennis ball with occasional larger pieces as big as a man's head. The clinker falls from the lower end of the kiln into another revolving steel cylinder, equipped with longitudinal bars which keep lifting the hot clinker up and allowing it to drop through the in-rushing air. By this means the clinker is cooled. The cooled clinker emerges from the lower end of the

cooler and drops into a series of elevators which carries it into the clinker store. Through numerous holes in the floor of this store the clinker falls into a conveyor which carries it to the mill, where. in a ball mill and two tube mills similar to those used in the raw material mill, it is reduced to a fineness which leaves a residue of only about 5 per cent. on a sieve having 32,400 holes per square inch. Other conveyors and elevators take the finished cement to the storage bins. The capacity of the present plant is about 1,200 tons per week or about 60,000 tons per year.'

Sone Valley Portland Cement Company, Limited. (Cement Works, Japla, 3rd July, 1928.).

Limestone analyses, from Bhangia Gurosoto Limestone Quarry.

	Per cent.	Per cent.	Per cent.	Per cent.
SiO_2	10·78	10·52	10·05	9·78
Al_2O_3	1·52	1·38	1·22	1·36
Fe_2O_3	0·96	0·80	0·92	0·80
$CaCO_3$	83·50	84·00	84·70	85·20
$MgCO_3$	3·30	2·98	2·57	2 88
Alkalies	..	0·32	0·54	..
TOTAL	100·06	100·00	100·00	100·02

The author is much indebted to Messrs. Killick, Nixon and Company for the following particulars of the Bundi and the Punjab Portland Cement Works, to Messrs. Macdonald and Company for those of the Katni Works, and to the various managers and chemists at the factories.

Bundi Portland Cement Co., Ltd., Lakheri, Bundi State, Rajputana.

It is a matter of extreme importance to the Bundi Portland Cement Works to know the exact composition and lateral variation of each band in the limestone (the Lower Bhander in the Upper Vindhyans). Numerous analyses have been made by the chemist to the company, Mr. A. Weighell, and the figures of some of the lime quarry and cement quarry analyses have been kindly supplied by the Managing Agents, Messrs. Killick, Nixon and Company.

Lime quarry samples.

—	Number of analyses. Red Floor. 3	White. 7	Top Red. 7
SiO_2 (calcined)	Per cent. 27·12	Per cent. 22·77	Per cent. 23·01
SiO_2	18·32	14·67	14·97
Al_2O_3	4·64	3·34	3·09
Fe_2O_3	1·76	0·53	0·94
CaO	41·53	44·88	44·74
MgO	0·93	0·75	0·74
CO_2	31·37	34·73	34·61
Combined H_2O	0·82	0·73	0·73
TOTAL	99·37	99·63	99·82
Calcimeter figure	71·2	78·9	78·7
Ratio $\frac{SiO_2}{Al_2O_3}$	3·97	4·40	4·84

Cement quarry samples.

Bench numbers.	1	2	3	4
Number of analyses.	10	10	10	5
SiO_2 (Calcined)	Per cent. 25·85	Per cent. 24·06	Per cent. 25·58	Per cent. 26·60
SiO_2	16·98	15·68	16·87	17·85
Al_2O_3	3·01	3·19	3·80	3·84
Fe_2O_3	0·94	1·19	1·24	1·63
CaO	43·36	43·71	42·56	42·11
MgO	1·03	1·09	1·06	1·24
CO_2	33·33	33·74	32·94	31·80
H_2O, etc.	1·00	1·05	1·05	1·02
TOTAL	99·65	99·65	99·58	99·49
Calcimeter figure	75·7	76·6	74·9	72·2
Ratio $\frac{SiO_2}{Al_2O_3}$	5·64	4·91	4·37	4·65

The Bundi Portland Cement Works have a modern plant with every possible labour-saving device. They have recently installed a new crushing plant and the output of the works is likely to be considerably increased in consequence. The stone reserves of the company are immense, but the overburden is increasing as the quarries are extended to the north. Though at present scoops have to be utilised, there are many years reserves in actual sight. The company have the sole rights for limestone in Bundi State.

The works are conducted on up-to-date lines, the raw materials as well as the finished product being, at regular intervals, sampled and analysed by the chemist.

Punjab Portland Cement Co., Ltd., Wah (Attock Dist.).

Raw materials.—

Limestone.—Black Nummulitic limestone, markedly bituminous analysing up to 98 per cent. $CaCO_3$. Small hills of this rock lie close to the factory, constituting outlying spurs of the distant Margala hills.

Clay.—Alluvial clay is dug from the foot of these hill-masses. It is a pure, fine-grained, silty clay, free from sand. Its aluminium content is 19 per cent. which, according to the chemist of the works, is high and is giving trouble.

Gypsum.—A small quantity of gypsum (from Khewra) is used for mixing with the clinker before grinding, as a retarding agent.

The limestone crushers, elevators, mixers, slurry tanks, agitators, grinders, etc., are of modern type. There is an elaborate water purification plant for bringing the hardness of the water used (obtained from tube-wells at some distance) down to the proper degree suitable for cement manufacture. The furnace is a cylinder of 6 feet diameter and about 175 feet in length. The maximum heat at the farthest end of the feed (where the fusion takes place) is about 1,500°C. Pulverised coal from Dandot (Salt Range), and Dishergarh slack are used for fuel. The daily output is 100 tons, day and night working. The sacking, etc., is done by machinery. The grinding of the clinker is a little finer than is the case with imported Portland cement.

The output of cement is 5,500 tons per month. The factory commenced working before the War and is said to be in a very flourishing condition.

Raw Materials---

The Katni Cement and Industrial Co., Ltd., Tikuri, about 2 m. South of Katni, G. I. P. Railway.

Limestone.—One quarry is being worked in the Vindhyan limestones, about a quarter of a mile from the works. The limestones are of the dark-grey flaggy jointed variety, and dip at about 40° to the north-west. There is an overburden of about 40 feet of laterite and bauxite and light yellow and pink clays to be removed. According to the general manager, Mr. J. Boyd, the limestone occurs deeper to the north-west and appears to be somewhat lenticular, dying out along the strike. Almost all the rock in this quarry is of good quality, from 80 to 96 per cent. $CaCO_3$. Additional good limestone is obtained from about 20 miles away.

Clay.—The clay, which is mixed with the crushed limestone, is dug from the trap soil which forms the overburden of the above-mentioned limestone quarry.

Gypsum.—Gypsum used for retarding the speed of setting of the cement has to be brought from Khewra, Salt Range, Punjab. It contains 98 per cent. $CaSO_4.2H_2O$.

Coal.—Slack coal from the Bengal coalfieds is largely used, one of the Burhar seams being quite good. The Umaria coal is usable if a little care is taken in picking the coal.

The plant is electrically driven and is very up-to-date; work continues night and day. The limestone and clay ingredients, after being properly mixed in the correct proportions, are burnt in a long revolving steel cylinder, lined with fire-brick. The powdered coal is fed in with a blast of air from the opposite end of the cylinder. The temperature in this end of the cylinder where the final heating and conversion to Ca-Al-silicates takes place, rises to 1,600°C. Two of these revolving furnaces are kept going continually.

In addition to the cement factory, there is a more recently constructed firebrick and pottery works adjoining, and under the same management. Firebricks have been made to supply the needs of the cement factory, but the manufacture of pottery is still in the experimental stage. The clay is obtained from Jubbulpore, from Chandia, Rewah State, and other local places.

There is a rapid sale for all the cement which is manufactured.

Clays.

(E. L. G. Clegg.)

Importance of clay as a mineral product.

The important part played by clay in the industrial development of a country is not generally recognised, but can easily be illustrated by reference to the mineral statistics of such an industrially advanced country as the United Kingdom. In 1927, clay ranked second in value amongst the mineral products of that country; the output in that year being 18,081,213 statute tons valued at £3,820,373. The figures, in 1922, for the United States relate only to the manufactured products but reach the total value of £72,572,100. The magnitude of this total can be grasped when it is pointed out that this was more than three times the value of the total Indian mineral output for the same year of all minerals for which reliable statistics were available.

Production in India.

No statistics approaching any degree of completeness are obtainable to show the extent of the undoubtedly great industrial value of the clays in India. Figures for the production during the last quinquennium show a slight decrease over those of the previous period. These figures include the finer varieties of clay used for glazed pottery; fire-clays raised in considerable quantities on some of the Gondwana coalfields; Fuller's earth, which is mined in the Central Provinces, Mysore and Rajputana; and China clay which is produced mainly in Bihar and Orissa, Mysore and Jubbulpore. How incomplete these figures must be can be understood when it is realised that there is hardly a village in India without its local potter, who provides every household with cooking utensils, water vessels and other hollow ware articles made on the potters wheel, and that near practically every large village in India there exists a brickfield which supplies the needs of the locality. No returns of the clay used in these local manufactures are available.

The output of clay for which returns are available is summarised in Table 121. From this it will be seen that the average annual output during the period 1924-28, has been 151,901 tons valued at Rs. 3,44,231; during the previous quinquennium the average annual output was 154,214 tons valued at Rs. 3,92,873.

TABLE 121.—*Production of Clay in India during the years 1924 to 1928.*

	1924		1925		1926		1927		1928		AVERAGE.	
	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*
	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*
Baluchistan .	(a)	*500*	..	..	..	..	..	..	..	..	..	*(b) 100*
Bengal . .	26,544	*54,457*	43,602	*44,900*	65,851	*1,25,492*	23,866	*43,049*	44,149	*87,759*	40,802	*71,131*
Bihar and Orissa	25,153	*1,64,783*	24,371	*1,21,096*	41,236	*2,22,403*	28,131	*1,60,264*	24,771	*1,84,863*	28,732	*1,70,682*
Burma . .	27,239	*29,206*	25,184	*32,895*	26,141	*36,939*	23,379	*36,301*	26,865	*37,584*	25,762	*34,585*
Central India .	556	*1,312*	1,256	*4,003*	58	*345*	489	*3,175*	864	*2,926*	644	*2,352*
Central Provinces	31,300	*19,646*	17,820	*9,407*	36,405	*22,185*	52,446	*31,775*	60,219	*57,569*	39,638	*28,116*
Delhi . .	2,573	*2,820*	2,133	*2,256*	3,791	*6,172*	4,300	*4,767*	..	..	2,559	*(b) 3,203*
Gwalior . .	475	*4,017*	579	*6,669*	162	*1,815*	600	*4,124*	743	*5,018*	512	*4,329*
Kashmir . .	..	..	1,147	*1,920*	1,544	*2,589*	919	*1,000*	958	*1,105*	914	*(b) 1,323*
Madras . .	107	*107*	708	*4,038*	265	*272*	1,094	*434*	17,366	*1,893*	3,908	*1,349*
Mysore . .	3,623	*28,556*	3,786	*14,294*	14,892	*18,505*	6,003	*21,168*	8,957	*43,914*	7,452	*25,287*
Rajputana .	437	*1,525*	562	*1,307*	714	*1,575*	709	*1,585*	684	*1,549*	621	*1,508*
United Provinces	..	..	..	..	1,779	*1,328*	..	..	..	..	356	*(b) 266*
TOTAL .	118,007	*3,06,929*	121,148	*2,42,785*	192,833	*4,39,620*	141,936	*3,07,642*	185,576	*4,24,180*	151,930	*3,44,231*
Total value in sterling.		*22,081* (£1 = Rs. 13·9)		*£18,254* (£1 = Rs. 13·3)		*£32,807* (£1 = Rs. 13·4)		*£22,959* (£1 = Rs. 13·4)		*£21,655* (£1 = Rs. 13·4)		..

(a) Not available. (b) Average of 5 years.

The Bengal output is derived mainly from the Burdwan district, where Messrs. Burn and Company's factory at Raniganj provides occupation for nearly 2,500 employees and turns out goods of various descriptions, amongst which the most important are glazed stoneware drain pipes and roofing and flooring tiles. The manufacture of refractories such as fire-bricks and silica bricks also forms an important branch of their industry. Fire-bricks and roofing tiles are also manufactured at the Kumardhubi fire-clay and silica works of Messrs. Bird and Company at Barakar, and at the Bengal Fire-brick Syndicate of Messrs. Martin and Company at Kulti in the same vicinity, whilst in the Madras Presidency the Basel Mission Tile Brick and Terra-cotta works carry on the same manufacture.

The output of the Central Provinces is mainly from the Jubbulpore district with a small production from the Hoshangabad district. The main portion of the Jubbulpore output is derived from quarries in the Upper Gondwana rocks near Jubbulpore town and is used in the pottery works of Messrs. Burn and Company and the Perfect Pottery Company. A certain amount of clay is also won by the Katni Cement and Industrial Company at Tikuri near Katni.

China clay.

India also possesses resources in China clay or kaolin. This is used extensively in industry for the making of high grade pottery, cotton dressing, paper filling, soap making, paint mixing, rubber manufacture and in medicines. Its value for purposes other than pottery lies mainly, when properly refined, in its perfect whiteness, fineness, so-called colloidal properties and its harmlessness when used edibly. The China clay and fire-clay deposits of the Rajmahal hills were investigated by Dr. Murray Stuart[1] who reported most favourably on their suitability for manufacturing porcelain and fire-bricks of the highest quality. The Calcutta Pottery Works have used kaolin from Mangal Hat in the latter area and have succeeded in producing cups, saucers, jugs and ornaments of common white porcelain. Mr. F. B. Kerridge[2] in a paper on 'The Working and Refining of Indian Kaolin with special reference to a Singhbhum deposit', gives the following tables showing the results of a number of analyses made of samples of China clay taken at random from ordinary consignments received from Cornwall, and of samples of clay prepared at the Kasimbazar mines at Hat Gumaria, 30 miles south of Chaibassa in the Singhbhum district of

[1] *Rec. Geol. Surv. Ind.*, XXXVIII, pp. 133-148 (1909).
[2] *Trans. Min. Geol. Inst. Ind.*, Vol. XXIV, pp. 295—320 (1930).

Bihar and Orissa. Mr. Kerridge observes that 'chemically the Indian clay compares favourably with the English variety except in regard to lime and magnesia content, but that so far as alumina and combined silica are concerned, there is but little difference in the two clays'.

Sample No.	Alumina.	Oxide of iron.	Lime.	Magnesia.	Combined silica.	Insoluble silica.	Moisture and water of hydration.
English Imported Clays.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1	36·53	1·17	0·20	0·36	42·01	7·05	12·51
2	38·87	1·30	0·25	0·54	45·17	1·70	12·08
3	37·02	1·60	0·20	0·36	46·07	1·06	12·69
4	35·88	1·57	0·30	0·36	45·42	3·63	12·20
5	35·49	1·21	0·30	0 29	46·55	2·52	13·30
6	35·35	0·85	0·40	0·51	45·48	4·63	12·21
Average .	*36·52*	*1·28*	*0·27*	*0·40*	*45·11*	*3·53*	*12·49*
Singhbhum Clays.							
1	37·13	0·67	0·71	0·79	43·28	3·68	13·30*
2	37·43	0·57	0·66	1·02	44·19	4·32	11·10
3	35·58	1·22	0·96	0·90	43·25	7·05	10·29
4	38·27	1·03	1·03	0·55	43·86	4·90	10·13
5	34·26	1·24	1·13	0·52	43·01	4·84	14·38*
6	35·05	0·62	0·68	0·12	46·88	4·52	11·76
Average .	*36·28*	*0·89*	*0·86*	*0·65*	*44·07*	*4·88*	*11·48*

* These two samples were obviously not 'Dry' when analysed.

For paper filling the Singhbhum product has completely cut out the imported China clay in the paper mills managed by Messrs. Bird and Company in the Calcutta vicinity, in which mills over 3,000 tons of China clay are used per annum. A considerable amount of clay of a light pink colour but remarkable purity from the same locality has also been used successfully in the Calcutta Pottery Works for 'stoneware' acid jars.

Production of China clay.

Table 122 shows the production of China clay in India during the quinquennium under review. The most striking feature brought out by this table is the average figures for Bihar and Orissa, 6,417 tons valued at Rs. 63,422 with an average value of Rs. 9 as. 14

TABLE 122.—*Production of China Clay in India during the years 1924 to 1928.*

—	1924		1925		1926		1927		1928		AVERAGE.	
	Quantity.	*Value.*	Quantity	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*
	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*
Bihar and Orissa—												
Seraikela	457	*8,881*	99	*2,440*	13	*262*	20	*550*	..	..	118	*2,427*
Bhagalpur	1,155	*4,950*	2,625	*11,250*	3,870	*11,610*	4,490	*13,470*	3,310	*10,800*	3,090	*10,416*
Singhbhum	1,137	*24,350*	1,735	*20,837*	3,351	*44,082*	5,948	*71,130*	3,876	*92,500*	3,209	*50,579*
Central India	556	*1,312*	1,256	*4,003*	58	*345*	489	*3,175*	864	*2,926*	645	*2,352*
Central Provinces—												
Jubbulpore	19,695	*9,232*	15,943	*7,594*	..	..	..	..	..	..	(b)7,128	*(b)3,365*
Delhi	2,573	*2,520*	2,133	*2,256*	3,791	*6,172*	4,300	*4,767*	..	..	(b)2,559	*(b)3,203*
Gwalior	475	*4,017*	579	*6,669*	162	*1,815*	600	*4,124*	743	*5,018*	512	*4,329*
Madras—												
Cuddapah	107	*107*	338	*338*	265	*272*	374	*374*	349	*349*	287	*288*
Mysore	2,309	*22,843*	1,391	*12,854*	1,324	*10,025*	6,003	*21,168*	8,957	*43,914*	3,997	*22,161*
Rajputana—												
Bundi	400	*1,210*	526	*981*	680	*1,290*	670	*1,270*	650	*1,255*	585	*1,201*
Jaisalmer	37	*315*	36	*326*	34	*285*	39	*315*	34	*294*	36	*307*
TOTAL	**28,901**	*80,037*	**26,661** (a)	*69,548*	**13,548**	*76,158*	**22,933**	*1,20,343*	**18,793**	*1,57,056*	**22,165**	*1,00,628*

(a) Excludes 19,421 tons of China clay produced from Burdwan in Bengal.
(b) Average of five years.

per ton, against an average total production of 20,432 tons valued at Rs. 40,705 giving an average value of Rs. 2 per ton for the rest of India. The high value of the kaolin from Bihar and Orissa is due to the cost of the levigation processes to which the clay is subjected before being sold for paper filling, soap making, paint mixing and other of the more refined uses for which it can be utilised. The steady advance made by the Bihar and Orissa China clay has also been brought out. A production of 2,749 tons in 1924, steadily increased to a maximum of 10,458 tons in 1927, only to fall in 1928 to 7,186 tons. This decline is, however, only apparent as the large total produced in 1927 was due to over-production to accumulate stocks, to tide the producers over the monsoon periods, when the quarries are flooded and no refining can be carried out.

In Table 123 will be found the imports of China clay into India by provinces. The advance of the Bihar and Orissa industry is reflected in the decrease in imports of China clay into Bengal since 1925-26. Up to 1926-27, the imports of China clay into India steadily advanced but the year 1927-28, shows a decline of 43 tons. This decline is very small but may, if the Indian producers keep up the quality of the refined product, be the harbinger of a greater decline in the future when, there seems little doubt, the Bihar and Orissa China clay will completely oust the Cornish clay for all purposes in the Bengal market.

Fullers' Earth.

Fullers' earth is obtained at Katni in the Jubbulpore district of the Central Provinces where it occurs in the Lower Vindhyan series. A form of Fullers' earth is also worked in the states of Bikaner and Jaisalmer in Rajputana; this and other varieties are eaten in various parts of India. A steady supply has been derived from Rajputana and Mysore during the period under review but the Jubbulpore output has only been sporadic.

In Table 124 will be found the production of Fullers' earth in India for the quinquennium under review. The average annual production is 3,169 tons valued at Rs. 21,706 and shows a marked decrease over the figure for the previous quinquennium, which was 9,585 tons valued at Rs. 24,640. Mysore produced an increased tonnage of 937 tons but the Rajputana states, the main producers, show a decrease in production of 7,234 tons.

TABLE 123.—*Imports of China Clay into India during the years 1923-24 to 1927-28.*

	1923-24		1924-25		1925-26		1926-27		1927-28		AVERAGE	
	Quantity.	Value.	Quantity	Value.	Quantity	Value	Quantity.	Value.	Quantity	Value.	Quantity	Value
	Tons	Rs	Tons	Rs	Tons.	Rs	Tons	Rs	Tons.	Rs	Tons.	Rs.
Bengal . .	1,087	89,995	3,263	2,54,238	4,952	2,93,672	4,39[illegible]	2,91,[illegible]	3,547	2,39,442	3,460	2,33,[illegible]
Bombay .	16,689	14,67,062	18,810	16,01,124	16,649	13,04,429	21,957	16,[illegible]	22,[illegible]4	15,97,[illegible]	19,416	15,29,438
Sind . .	.		.		4	37[illegible]	..	.	.	..	.	..
Madras . .	310	30,[illegible]	3[illegible]	38,233	46[illegible]	41,002	375	[illegible]	149	13,[illegible]	339	31,1[illegible]2
Burma .	20	2,045	2	1[illegible]7	11	6[illegible]3	2	1[illegible]9	1[illegible]	784	9	76[illegible]
TOTAL .	13,1[illegible]6	15,89,985	22,472	18,93,722	22,082	16,40,171	28,733	20,01,643	2[illegible],890	18,50,919	23,216	1[illegible],95,213

TABLE 124.—*Production of Fuller's Earth during the years 1924 to 1928.*

—	1924		1925		1926		1927		1928		AVERAGE	
	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*
	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons	*Rs.*	Tons.	*Rs*	Tons.	*Rs*
Central Provinces—												
Jubbulpore . . .	13	*93*	59	*289*	..		35	*173*	76	*374*	38	*186*
Mysore	2,534	*364*	143	*364*	1,479	*3,759*	214	*539*	457	*550*	965	*1 117*
Rajputana—												
Bikaner . . .	450	*2,010*	1,180	*7,090*	913	*5,511*	1,469	*9,335*	1 836	*11,020*	1,171	*6,991*
Jaisalmer . . .	5	*85*	20	*310*	21	*326*	23	*345*	25	*351*	19	*283*
Jodhpur . .	1,070	*13,475*	796	*13,434*	1,038	*14,005*	977	*12,222*	1,000	*12,509*	976	*13,127*
TOTAL .	**4,078**	*16 027*	**2,198**	*21,477*	**3,456**	*23,601*	**2,718**	*22,[illegible]14*	**3,394**	*24,813*	**3,169**	*21,706*
Total value in Sterling .		*£1,153* (£1 = Rs. 13·9)		*£1 615* (£1 = Rs. 13·3)		*£1,761* (£1 = Rs. 13·4)		*£1, 87* (£1 = Rs. 13·4)		*£1,852* (£1 = Rs. 13·4)		*£1,614*

Imports.

The imports of materials coming under this section—namely earthenware and porcelain, earthenware piping, bricks and tiles and clay are shown in Table 125 from which it will be seen that they increased up to 1926-27, but correspondingly decreased during the remainder of the period. The average annual value of these imports was Rs. 1,04,51.343 as compared with Rs. 1,18,48,759 during the preceding five years, a decline of just over 8 per cent. but one which is likely to be continuous in the future.

TABLE 125.—*Value of imports into India of Clay and Clay Products during the years 1924-25 to 1928-29.*

Year.	Earthenware and porcelain.	Earthenware piping.	Bricks and tiles.	Clay.	**Total annual imports.**
	Rs.	Rs.	Rs.	Rs.	Rs.
1924-25 . . .	72,28,495	2,58,723	24,59,807	79,619	**1,00,26,644**
1925-26 . . .	73,51,264	2,93,411	27,42,849	69,110	**1,04,56,634**
1926-27 . . .	81,78,753	1,03,358	28,78,146	90,170	**1,12,50,427**
1927-28 . . .	80,20,274	50,596	25,97,850	83,080	**1,07,51,800**
1928-29 . . .	72,55,591	53,703	23,82,122	79,796	**97,71,212**
Average .	*76,06,875*	*1,51,958*	*26,12,155*	*80,355*	**1,04,51,343**

As the average value of the exports and re-exports of clay and clay products during the period has amounted only to Rs. 7,80,318, the total Indian consumption of such products exceeds the internal production by Rs. 96,71,025 indicating considerable scope for the development in the country of industries making use of clay.

Cobalt.

[E. H. PASCOE.]

Cobaltite, a sulph-arsenide of cobalt, and danaite, a cobaltiferous arsenopyrite, have been found as minute crystals disseminated amongst the slates of the Aravalli series at Khetri[1] and other places

[1] *Rec. Geol. Surv. Ind.*, XIV, pp. 190—196 (1887); see also A. M. Heron; *op. cit.*, XLIV, p. 19 (1914).

in Rajputana. These ores have been used for the manufacture of various sulphates. The minerals were formerly separated for the production of *sehta*, which is used by the Indian jewellers for producing a cobalt-blue enamel. The sulphide of cobalt, linnæite (Co_3S_4), has been identified in the Geological Survey laboratory amongst some ores of copper sent a few years ago from Sikkim by Colonel Newcomen. Some years ago specimens of a matte containing 11 to 14 per cent. of cobalt, the rest being iron and sulphur, were received in the Geological Survey Office from Nepal, but no details as to the mode of occurrence have ever been forthcoming; the matte is reported to have come from Kachipatar Argah, *zillah* Sowrobhar, about 80 miles north of Doolha.[1] Small quantities of cobalt and nickel are frequently detected in the Indian manganese ores; the best sample is the cobaltiferous wad of Olatura in the Kalahandi state, a specimen of which yielded 0·82 per cent. of cobalt oxide (CoO).

Since 1927, there has been a regular production of nickel speiss as a by-product in the smelting operations of the Burma Corporation, Limited, at Namtu in the Northern Shan States of Burma. This speiss, which in 1927 amounted to 1,032 tons and in 1928 to 2,933 tons, contains from 3 to 4 per cent. of cobalt, and is shipped to Hamburg for further treatment (*See* Nickel).

Corundum.

[E. H. PASCOE.]

The use of abrasives in manufacturing communities is still on the increase, and new artificial forms are frequently being put on the market. Emery formerly served most requirements, until purer forms of corundum were discovered in quantity. The cheaper forms of garnet have long been used to adulterate emery, and members of the spinel family, such as hercynite, have been used inadvertently as such. During the last thirty-five years carborundum, manufactured by the cheap electrical power developed in America, has come into use, the production of the United States having now reached an average figure of over 20,000 short tons a year. Artificial forms of corundum are being manufactured from bauxite and the

[1] E. J. Jones; *Rec. Geol. Surv. Ind.*, XXII, p. 172 (1889).

use of artificial aluminous abrasives continues to grow; the annual output of artificial alumina in the United States has, on two or three occasions, exceeded 50,000 short tons.

Crushed steel is being used to a steadily increasing extent.

TABLE 126.—*Production of Corundum in India during the years 1924 to 1928.*

—	1924		1925		1926		1927		1928	
	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*
	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*	Tons.	*Rs.*
Central Provinces—										
Bhandara	..	..	10	(*a*)	11	*253*	13	*260*	..	..
Madras—										
Salem	..	..	..	..	17	*4,333*	52	*7,763*	21	*2,780*
TOTAL	..	..	10	(*a*)	28	*4,586*	65	*8,023*	21	*2,780*

(*a*) Not available.

Natural corundum has thus several competitors in the market of abrasive materials, and as a large portion of the alumina in igneous magmas is necessarily used up during the processes of consolidation by the silica and bases present, it is theoretically unlikely that the free oxide can exist anywhere in an abundance comparable to the vast quantities of combined alumina in the earth's crust. In most cases the corundum is scattered as isolated crystals through the rock, and only the most economical devices for its separation can make mining remunerative. Manufactured abrasives shew a general superiority over natural corundum, and the outlook for the latter industry is not encouraging.

In India, where the use of corundum by the old *saikalgar* (armourer) and lapidary has been known for many generations, the requirements of the country have been met by a few comparatively rich deposits, but it is doubtful if these are worth working for export in the face of the competition referred to above in Europe and America, or will even stand against the importation of cheap abrasives.

There is still, and for many generations has been, a certain trade in Indian corundum, but the returns for production are manifestly incomplete. No workings exist of the kind that could be ordinarily described as mining, but attempts have been made at times to increase the scale of operations at Palakod and Paparapatti in the Salem district of Madras, near Hunsur in Mysore, and in South Rewah.

The occurrence near Pipra in Rewah State was worked some years ago by Indian traders of Mirzapur. A peak production of 1,860 cwts. was obtained in 1913, but the supply fell to an average of nearly 400 cwts. during 1914-18. In 1919, it again rose to 1,471 cwts. followed by 882 cwts. in the following year, but the mines have not been worked since 1920. Small quantities of corundum were produced in the Bhandara district of the Central Provinces in 1925, 1926 and 1927 (see Table 126). Of the production of corundum recorded from the Madras Presidency, 211 cwts. from Coimbatore and 478 cwts. from Trichonopoly made up the supply for 1914, but throughout the remainder of the period (1915-18) the whole of the output, averaging 31½ cwts. annually, came from South Kanara. During the quinquennium 1919-23, there was no output from Madras. In 1926, 1927 and 1928 small outputs were reported from the Salem district (see Table 126).

Production.

Corundum is very widely distributed throughout the Mysore State and is said to occur in every district except Shimoga. In 1914, the output came from Kolar, in 1915, from Kolar (76 cwts.) and Tumkur (843 cwts.), and in 1916, from the Mysore district. The average annual production during the quinquennium 1914-18, was 523 cwts. valued at Rs. 1,560; there has been no recorded output for the past ten years.

Much of the corundum, which is a regular item of trade in the bazars of cities like Delhi, Agra, and Jaipur, where the Indian lapidary still flourishes, is collected in a casual way by agriculturists and cowherds, who dispose of it through the village *bania* to the larger dealers of the great cities. Our information as to the mode of occurrence and distribution of the mineral was summarised in a special memoir published by the Geological Survey in 1898.

The production of 'corundum with sapphire patches' in Kashmir State amounted to 1·6 cwts. in 1926, 11 cwts. in 1927 and 1 cwt.

in 1928. The mines are situated near Sumjam (Sumsam) in the Udhampur district, Jammu Province, and are under the direct control of the Mineral Survey Department of the State. The mines have not yet been regularly worked. Production is also reported from Mabbubnagar, Gulbarga, and Nalgonda in Hyderabad.

Khasi Hills.

Corundum (*mawshinrut*) is known to occur at three localities in the Nongstoin State in the north-west Khasi hills, but much of the material obtained in this province in recent years is now known to be sillimanite (*q. v.*). The localities have, so far, proved to be too difficult of access for the exploitation of either mineral on a large scale, but corundum is worked in small quantities and used all over the Khasi hills for hones.[1] The reported output of corundum from the Khasi hills was 12,660 cwts. in 1919, 3,320 cwts. in 1920, and 1,277·6 cwts. in 1921, but it is not known what proportion of this was sillimanite. No production of corundum is reported for the last seven years.

Gem varieties of corundum are treated under 'Gem-stones'.

Canadian corundum.

The chief producers of corundum and emery used to be Canada, Turkey and Greece, Canada supplying corundum, and Turkey and Greece emery. The Canadian corundum is found in Ontario in association with nepheline-syenite like that near Kangayam in the Coimbatore district.[2] By the adoption of mechanical means for concentration it became possible to separate corundum from the felspar-rock in which it was embedded, and to put a product on the market, not only for local use, but for export to the United States and Europe. The Canadian industry commenced in 1900, and the annual production for the five years 1914-18 averaged 240 tons valued at £6,876, an output which was less than one-sixth of what it had been before the war. The production of corundum in Canada ceased after the War, the last shipments to the United States, which are the largest consumer of the material, having been made in 1921. The principal source of supply for the United States to-day is the Zoutpansberg district of the Transvaal where the mineral occurs mainly as loose crystals in shallow eluvial deposits. In 1926, the Transvaal furnished nearly 6,000 short tons of corundum.

[1] F. E. Jackson; *Rec. Geol. Surv. Ind.*, XXXVI, p. 323 (1908).

[2] T. H. Holland; 'The Sivamalai series of Elæolite- and Corundum-Syenites,' *Mem Geol. Surv. Ind.*, XXX, pt. 3 (1901).

Fluor-spar.

[E. H. PASCOE.]

Fluor-spar has been obtained at Barla in the Kishangarh state, Rajputana, but the work of excavation was abandoned under a mistaken impression that the mineral was an inferior form of amethyst. Apparently the mineral here forms, with calcite and quartz, a vein about a foot in thickness traversing gneiss. This occurrence was investigated by the Tata Iron and Steel Company, who report that very little fluor-spar was present, and that the cost of working it would exceed that at which they are able to purchase it from Europe; their imports of fluor-spar for use as a flux in the manufacture of steel during the five years under review were as follows :—

	Tons.
1924	302
1925	886
1926	723
1927	1,096
1928	1,758

Imports during the previous period averaged 500 tons a year.

Fluor-spar has also been found as small crystals in a dyke of quartz-porphyry near the copper-ore lodes of Sleemanabad, Jubbulpore district[1]; another occurrence in the Central Provinces is known at Chicholi in the Drug district, where fluor-spar accompanies galena and copper carbonate in a quartz vein traversing gneiss.[2] Other localities recorded for the mineral are: near Rewah[3] in one of the Vindhyan limestones; in the granitic veins of the Sutlej valley, North-West Himalaya[4]; and in limestone in the Amherst district, Burma. Fluorite was found associated with orpiment and realgar at Mirgasht Gol in the Tirich valley, Chitral. It has also been observed in a joint of Coal Measure shale adjoining a decomposed dolerite dyke in the neighbourhood of Rawanwara, Chhindwara district, Central Provinces. No indication of large deposits has been noticed at any of the localities.

Garnet.

(*See* 'Gem-stones of lesser importance'.)

[1] L. L. Fermor; *Rec. Geol. Surv. Ind.*, XXXIII, p. 63 (1906).
[2] W. T. Blanford; *Ibid.*, III, p. 44 (1870).
[3] F. R. Mallet; *Mem. Geol. Surv. Ind.*, VII, p. 122 (1871).
[4] F. R. Mallet; *Ibid.*, V, p. 166 (1866).

Gem-stones of lesser importance.

[E. H. Pascoe.]

The most valuable of the precious stones raised in India is undoubtedly the ruby, but this and the other stones obtained in the country do not approach in value the unset stones and pearls imported, which, during the period under review, had an average annual value of Rs. 1,19,02,603 (compared with Rs. 1,17,44,719 during the previous quinquennium).

Of the precious and semi-precious stones in India, the most important, amber, diamond, jadeite, ruby, sapphire, and spinel, have been already referred to. Of the others, the only ones that are of immediate concern are agate, rock-crystal, beryl, garnet, tourmaline, and turquoise. All of these except the last have been or are still being worked to some extent in India ; the turquoise may be dismissed with the mere mention of the fact that India, besides being a large importer for local use, is one of the channels by which the material raised in Persia and adjoining areas reaches the European and Eastern market. The other minerals—with some other Indian stones at present used very little or not at all—deserve more particular mention.

Agate.

Up to about a dozen years ago there had been a considerable trade in agate and the related forms of silica, carnelian, onyx, etc., known under the general name of *hakik*, and obtained from the amygdaloidal flows of the Deccan trap. The best known and most important of the places at which agate and carnelians have been cut and prepared for the market is Cambay, the chief city of the state of that name under the Kaira Political Agency, Bombay Presidency. The agates come from various states and districts on or near the edge of the trap, the chief sources of supply being the Kistna, Godavari, Bhima, Narbada and other rivers draining trap-covered areas. A large proportion of the pebbles comes from the state of Rajpipla. An account of the Rajpipla agate industry has been given by Mr. P. N. Bose.[1] The agates occur in a conglomerate of probably Pliocene age, and have been worked chiefly at Ratanpur and Damlai. The stones are chipped at the mines, and those approved of taken to Limodra, where they are baked. The baked stones are sent to Cambay for

[1] *Rec. Geol. Surv. Ind.*, XXXVII, pp. 176—182 (1908).

cutting and polishing. The Rajpipla *hakik* mines are leased for periods of five years at a fixed annual rental or royalty. This was Rs. 3,000 a year for the period 1902-06. No precise data as to the value of the stones sent to Cambay are available. The Rajpipla mines have not been worked since 1917. A certain amount of agate-cutting is also carried on at Jubbulpore in the Central Provinces, at Banda in the United Provinces, and at a few other places within range of the Deccan trap. Much of the agate retailed in Europe is sent from Cambay, and large quantities are also exported to China from that city.

Various forms of quartz—rock-crystal, amethyst, etc.—are used by jewellers in various parts of India.

Rock-crystal.

In the Tanjore district, Madras Presidency, fragments of rock-crystal are collected and cut for cheap jewellery, being known as 'Vallum diamonds', whilst the bipyramidal quartz-crystals, found in the gypsum of the salt-marl near Kalabagh and Mari, on the Indus, are to a certain extent used for making necklaces; these crystals are sometimes known as 'Mari diamonds'. Rock-crystal is similarly used for cheap jewellery in Kashmir. Fine pieces of rock-crystal are sometimes cut into cups, sword handles, and sacred objects, such as *lingams*, in Northern India. An exceptionally fine crystal of transparent quartz came to light in Burma in 1925. A ball, 30 inches in diameter and 130 lbs. in weight, was cut from the mass in China, polished in Japan and found its way to the United States National Museum at Washington. The crystal is presumed to have come from the Sakangyi area near Mogok.

Amethyst and rose-quartz.

Small amethysts, usually of uneven colour, are obtained at many places from Deccan trap geodes, *e.g.*, in the bed of the Narbada near Jubbulpore, and used for jewellery and beads. Amethyst is common in the Sutlej valley in Bashahr, Punjab[1]. Rose-quartz is found in the Chhindwara district, at Warangal in Hyderabad and in other places[2]; it is used in cheap jewellery.

Apatite.

Green apatite derived from pegmatites in Ajmer in Rajputana is sometimes cut into gem-stones, and a considerable quantity of apatite of a rich sea-green colour has been found at Devada, Vizagapatam district,

[1] H. H. Hayden; *Mem. Geol. Surv. Ind.*, XXXVI, p. 102 (1904).
[2] L. L. Fermor; *Ibid.*, XXXVII, p. 212 (1909).

Madras, derived probably from a pegmatitic variety of kodurite.[1] Crystals of a beautiful blue colour are occasionally found in the gravels of the Mogok Ruby mines.

Beryl.

Beryl in its pale-coloured varieties is of common occurrence in the granite-pegmatites of India, but the crystals are generally too much fissured for use as gem-stones. Occasionally in the pegmatite veins, which are worked for mica in Bihar and in Nellore, large crystals of beryl, many inches across, are found to include clear fragments which might be cut as aquamarines; but the only places in India where attempts have been made to excavate pegmatite solely for its aquamarines are at Padyur (Pattala) near Kangayam, Coimbatore district, where they accompany the mineral clevelandite, at different places in the Toda hills in Rajputana, and in the Skardu *tehsil* of Kashmir. Stones of considerable value were obtained from the mine which was worked at Padyur in the early part of the nineteenth century; a pit some 30-40 feet in depth is still in existence, but no one seems to have taken an interest in the place since Mr. J. M. Heath held a lease in 1818. The whole area is impregnated with igneous intrusions and deserves more attention than it has so far received.

An output of 1,293 carats of beryl valued at Rs. 95 was reported from Ajmer-Merwara in Rajputana in 1925. At Sagar near Sarwar in the Kishangarh state, Rajputana, aquamarines occur in mica-bearing pegmatites.

The occurrences in Kashmir have proved to be of considerable importance and a paper by Messrs. C. S. Middlemiss and Lala Joti Parshad has already appeared in the Records of this department.[2] The principal source of the stones is the immediate neighbourhood of Daso village, but evidence has been obtained to shew that beryls and aquamarines occur further away up the Braldu and Basha valleys and also in the Rondu neighbourhood. The gems are found in veins of coarse pegmatite traversing foliated biotite-gneiss. They do not, as a rule, shew great depth of colour but the tint is delicate and limpid. In 1915, 3·75 cwts. of beryl of varying quality were obtained in Skardu; the total value is not known but Calcutta and Lucknow jewellers offered from one to four annas a *rati* for clear transparent crystals. In 1916, the supply increased to 4·13 cwts. In the dull state of the market for precious and semi-precious stones

[1] *Mem. Geol. Surv. Ind.*, XXXVII, p. 206 (1909).
[2] *Rec. Geol. Surv. Ind.*, Vol. XLIX, pp. 161-172 (1919).

it was impossible to form any precise idea of the value of this yield, but it was said to be several thousands of rupees; transparent varieties fetched from $2\frac{1}{2}$ to 4 annas a *rati*. In 1917, a test experiment with 20 workmen during 10 days yielded:—A-1 quality, 7,888 carats; 1st quality, small, 7,540 carats; and 2nd quality, large, 10,440 carats; the total value being close on £300. The deposits have as yet been only superficially opened up, and a long life for these mines is anticipated. During the past quinquennium the only outputs reported are 20 lbs. in 1920, and 55 lbs. in 1921.

Chrysoberyl.

Platy crystals of chrysoberyl have been found in the corundum-bearing felspar-veins near Kangayam in the Coimbatore district, associated with nepheline syenites, but the crystals are too highly flawed to be suitable for gems. Yellow crystals, transparent and of good quality, are said to occur with mica and aquamarine in pegmatite veins at Govindsagar, Kishangarh State, Rajputana.

Garnet.

Garnets have been worked to some extent in India from the mica-schists of Rajmahal in Jaipur State, at Shahpura in Udaipur State, in the Sarwar district of Kishangarh State, and in the district of Ajmer-Merwara, all these localities being within a relatively small distance of each other. Returns have not been available to show the condition of the industry in the Jaipur state, but the statistics obtained in the past indicated the existence of a considerable industry in the other areas. All these mines were closed during the five years 1924-28. The Kishangarh garnets are stated to be the finest in India.

It is convenient to record here a deposit of massive garnet, which might be useful for abrasive purposes, noted by Dr. Heron in 1924, at Sarsiri, a village in Ajmer, 5 miles from Mangliawas railway station, and 16 miles south of Ajmer Junction. The country rock is a dense, tough, dark-green, banded granulite interbanded with white crystalline limestones. The garnet is reddish brown, and forms some 15 irregular bands more than a foot in thickness with innumerable smaller lenticles and vein-like bodies. The largest band north of Sarsiri is from 6 to 12 feet wide, forms an outcrop 15 feet high in places, and can be traced running vertically along the strike for about 300 yards. This band is not solid garnet from wall to wall, but includes streaks of quartz, calcite, a green ferro-magnesian mineral and country rock; garnet, however, forms roughly four-fifths of the whole. Dozens of loose blocks, 2 or 3 feet across, of

almost pure garnet are strewn along the outcrops of the chief bands. Sarsiri is connected with Mangliawas station by a semi-metalled road over a flat country, and ample labour is available from large villages near at hand.

The garnets worked in India belong to the almandite variety, and have a purple colour. Stones of large size were obtained and their cutting for the market formed an important industry in Jaipur and Delhi. Garnets of small size but rich colour are very plentiful in the sands of the Travancore coast.

Garnets are also found in other parts of India, as in the Tinnevelly district, Madras,[1] which produced about 1,000 tons of garnet sand for abrasive purposes in 1914; the workings, however, were closed down the following year, and remained so till 1927, during which some 285 tons were recovered; in 1928, 480 tons were collected. During the previous quinquennium 558 cwt. of stones were collected at Khammamet in the Warangal district of Madras and exported to Europe. Attention may be drawn to the fact that the manganese garnet, spessartite, so characteristic of the gonditic rocks of the Central Provinces, is in America sometimes used as a gem. The Indian variety varies from a beautiful bright orange to red-brown, but has not yet been found sufficiently free from flaws to be of use as a gem.[2] Garnets are widely developed in the banded gneiss, schist and granite of Chitral; many of the stones are of pleasing colour but are usually too flawed to be of value as gem-stones.

A large portion of the high ground between Afghanistan (Kafiristan and Wakhan) and Chitral is composed of garnetiferous and chiastolite-bearing schists with large masses of granitic intrusions. These intrusions are variable in size and mode of occurrence, and are usually fine-grained. In one of the coarser varieties at Sirwigh-o-gaz (12,000 feet), a summer grazing ground on the road from the Lutkuh to the Arkari, beryls were observed by Mr. Tipper in 1922. A few stones of poor quality, white and badly flawed, were seen *in situ*, but in the sandy debris below the rock good hexagonal crystals were found in considerable quantities; the latter are of pleasing colour, but the majority are somewhat badly cracked and contain lines of inclusions parallel to the basal cleavage. Some of the specimens were almost of gem quality, and the locality was thought to be worth further prospecting.

[1] L. L. Fermor; *Rec. Geol. Surv. Ind.*, XXXIII, p. 234 (1906).
[2] L. L. Fermor; *Mem. Geol. Surv Ind.*, XXXVII, p. 604 (1909).

Hyalite.

An output of 12·5 cwts. of hyalite, a colourless variety of opal, valued at Rs. 5,282, was reported from Katha in Burma, in 1923, but none was found during the quinquennium under review.

Iolite.

Cordierite or iolite, a mineral exhibiting striking pleochroism, is found in the gem gravels of Ceylon, and cut as a gem under the name of lynx-sapphire and water-sapphire. A polished and roughly engraved piece of iolite found in some excavations at Budh Gaya, and showing strong pleochroism, deep violet to nearly colourless, has long been in the Indian Museum but no locality for the mineral was known.[1] It has now been found at two localities, namely, in complex rocks composed of sillimanite, hypersthene and biotite, in the Vizagapatam Hill-tracts,[2] and in the Kadavur *zemindary*, Trichinopoly district, Madras, where Mr. P. N. Bose reports its occurrence in abundance near Udaiyapatti and Kiranur associated with labradorite and mica-schist. There are ancient pits dug apparently for this mineral.

Kyanite.

Kyanite is found at many localities in the Archæan formations of India and is occasionally used as a gem-stone on account of the fine blue colour it sometimes displays.[3] An authenticated locality for gem kyanite is Narnaul, Patiala State. The jewellers at Patiala call it *bruj*, and used to say that it sold at Rs. 3 to Rs. 5 per *tola*, a rate equivalent to 10*s.* to 16*s.* 8*d.* per ounce.[4] Kyanite is also plentiful in Kanaur and Bashahr in the Punjab Himalaya[5] where it has often been mistaken for sapphire.

Rhodonite.

Rhodonite, a manganese-pyroxene, is used abroad (*e.g.*, in the Urals) as a gem, and cut into all kinds of ornamental objects. It is found at many localities in India associated with manganese-ore deposits, and although none of it has yet been used for ornamental purposes, suitable material for the manufacture of small objects could be obtained at several of the mines.[6]

[1] V. Ball; *Proc. As. Soc. Beng.*, 1881, p. 89.
[2] T. L. Walker; *Rec. Geol. Surv. Ind.*, XXXVI, p. 13 (1908).
[3] M. Bauer and L. J. Spencer; ' Precious Stones,' p. 415 (1904).
[4] P. N. Bose; *Rec. Geol. Surv. Ind.*, XXXIII, p. 59 (1906).
[5] H. H. Hayden; *Mem. Geol. Surv. Ind.*, XXXVI, p. 102 (1904).
[6] L. L. Fermor; *Ibid.*, XXXVII, pp. 144-604 (1909).

The beautiful red tourmaline known as rubellite is worked on a small scale in the Ruby Mines district of Upper Burma. The production during the four years 1904 to 1907, averaged 101 lbs. valued at £750. Since then no figures have been received.

Tourmaline.

An interesting report was published in 1908, by Mr. E. C. S. George, Deputy Commissioner of the district,[1] on the workings for tourmaline round the small Palaung hamlet of Sanka about a mile east of Maingnin, where operations were carried on by the Chinese, according to local tradition, some 150 or 200 years ago. Mr. George states that after the Chinese deserted the area, the Kachins reopened the mines, but the industry was again interrupted until about 1885, when more systematic operations were commenced under Pu Seinda, who contracted to conduct all mining operations until 1895. The Möng-Mit (Momeit) stone-tract was afterwards notified by Government and regular licenses were taken up in 1899. During the years 1903 to 1905, the amounts recovered from 'tourmaline licenses,' the rate being Rs. 2 per worker per month, were Rs. 2,000 (£133) to Rs. 3,000 (£200) each year; since then they must have fallen off.

The tourmaline is found in soft, decomposed granite-veins, which, being generally covered by a thick deposit of jungle-clad soil, are found rather by accident than through the guidance of any superficial indications. Isolated crystals are found occasionally lying in the red soil, and men with small means sometimes find it profitable, when they have leisure, to search through the soil-cap by digging shallow pits. *Twinlons* or vertical shafts, about 4 to 5 feet square, are also put down on the chance of striking a tourmaline-bearing vein, or *kyaw*, and the owners of these *twinlons* are permitted to extend their workings underground to a radius of five fathoms from the centre of each shaft. Some of the workings extend to depths of about 100 feet, which appears to be about the limit of the miners' engineering skill. The tourmaline found is sorted into three classes: (1) *ahtet yay*, the best light-pink rubellite, of which there are two kinds, *hteik ti*, showing well-developed basal planes, and *be yan*, crystals terminated by rhombohedral faces, or with only a small development of the basal plane; (2) *akka*, of a darker colour, with the lower part of the crystals brown or black in colour; (3) *sinzi*

[1] *Rec. Geol. Surv. Ind.*, XXXVI, pp. 233-238 (1908).

or *arnyi*, all fragmentary crystals of any colour which are imperfect, or of a small size, less than about an inch. The *sinzi* is given without charge to the buyer of the lots of the two better kinds. The best kind, *ahtet yay*, may bring as much as Rs. 1,200 to Rs. 1,500 a viss (3·65 lbs.). The *myaw* system, or exposure of the veins on the hill-side by hydraulic action, has also been attempted at two localities with uncertain results: this work is limited to the Rains and is handicapped by the cost of leading the water-channels for long distances. All locally made purchases are effected by brokers, usually Shans or Shan Burmans. They in turn sell at Mandalay to purchasers for the Chinese market.

In 1909, 7 stones weighing 63·8 *ratis* or 37·5 carats,[1] valued at £26, were found in the Northern Shan States.

A beautiful green tourmaline with a crystalline limestone matrix is worked in a small way at Namon near the Salween river in the Southern Shan States. Green and blue varieties occur in the pegmatites of some parts of the mica-mining area of the Hazaribagh district, but the stones are not worth the cost of extraction.

Green tourmalines are also found at the Sapphire Mines area of Zanskar in Kashmir.

Zircon.

The mineral zircon is known in various parts of India, and where it occurs in the nepheline-syenite series near Kangayam in the Coimbatore district, it is picked up in small quantities and passed into the market as corundum; it is, however, nowhere found sufficiently transparent and flawless to be used as a gem. Similar material is met with in Travancore (*See* page 111).

Glass-making materials.

[G. V. HOBSON.]

As a result of the need created by the war of 1914-18 many countries, India included, developed their own glass-making re

[1] At 1 *rati* = 1$\frac{3}{4}$ grains troy = 0·592 carat.

sources. In 1919 it was estimated[1], on general grounds, that the glassware made in India was roughly one-fourth of the value of imported glassware. In the last quinquennial period before the war, 1909-13, three glass works were reported in operation; in 1921, there were no less than 32 firms engaged in the manufacture of glassware in India. At the beginning of the period under review the number was 17, and at the end of the quinquennium this number had only dropped to 16 (see Thacker's Indian Directory, 1929). It was inevitable that on account of severe competition, due to the influx of new enterprises into the glassware industry, many firms would be unable to avoid closing down. It appears from the above figures that the period of stabilisation, with the elimination of mushroom enterprises launched without sufficient financial or technical stamina, has now drawn to a close. There appears to be no reason why the Indian glass-making industry should not now prosper and gradually expand as a greater hold is established upon the local demand for the better finished class of goods, as well as on the demand for coloured and bottle glasses. The value of the potential market may be gathered from the table (TABLE 127) showing the value of glassware imported into India during the past quinquennium.

Raw materials.

An indigenous glass-making industry calls for a local source of supply of the raw materials required and of these by far the most important is silica sand. The action of the sand is purely chemical and usually the only useful constituent is silica so that the content of other materials should be as low as possible. Silica is a poor conductor of heat so that the silica particles must be small in order that the glass-making process may not be unduly prolonged. Chemical reaction proceeds at a rate closely connected with the contact between the reacting particles so again small particles are necessary for the rapid production of glass. Furthermore, large grains may remain undissolved in the resulting glass forming 'seeds' or 'stones'. Fineness of the particles is, however, limited by the cost of fine grinding and the danger of drawing the material out of the furnace by the draught and thereby disturbing the composition of the batch. Also the fines usually contain most of the impurities and washing-out the finest material may raise the grade of the sand. Very fine sand particles may remain in the glass instead of settling during the

[1] Industrial Handbook, Indian Munitions Board, p. 265.

'fining' process thereby giving a turbid glass. Limits of grain size for normal work may be taken as from 0·025 in. to 0·005 in. in diameter; but whatever limits are chosen it is desirable that all grains should be as uniform in size as possible. In the case of the Fontainbleau sand 79·6 per cent. consists of particles between 0·009 and 0·012 in. in diameter.

The sand may be a fine natural sand or may be got by crushing sandstone, quartzite, or other silica rock. Geyserite or siliceous sinter from deposits round hot springs has been used. European sands with a high silica content such as those from Fontainbleau (99·9 per cent. silica), Lippe (99·8 per cent. silica), Ashdown, Tunbridge Wells, and Aylesbury (99·5 to 99·8 per cent. silica), or the American sand from Berkeley Springs (99·65 per cent. silica) may be used for optical, crystal, and plate glass. For common ware—window glass, bottle glass, etc.,—the silica percentage need not be so high.

Sands of a degree of purity requisite for glass-making occur in several places in India. At Mangal Hat and Patraghatta, in the Rajmahal hills, there occur white Damuda sandstones which after crushing, washing, and sieving yield sand from which ordinary quality glass can be made. The presence of kaolin in this sand appears to be the cause of an infusible scum that forms on the top of the melt with the clear metal below; this scum would debar the use of the sand in pot furnaces, but would not be so serious in a tank furnace where the scum could be skimmed off. From Loghra and Borgarh (Naini) near Allahabad a suitable sand is obtained by crushing and grading a Vindhyan quartzite. Good quality sands can be obtained from Tertiary sandstone at Sankheda and from the Sabarmati river sand at Pedhamli, both in Baroda State. Sands of suitable quality are also reported to occur at Jubbulpore in the Central Provinces. A grit[1] occurs a mile south of Barodhia in Bundi State, Rajputana, which crumbles into a sand on the application of slight pressure and might be utilised for the purpose of glass manufacture, whilst the Infra-Trias limestones[2] in the vicinity of Garhi Habib Ullah and Muzaffarabad are silicified in a peculiar way resulting in the accumulation of large masses of soft, granular, almost powdery silica that might be used for the same purpose.

[1] *Rec. Geol. Surv. Ind.*, LIX, p. 51 (1926).
[2] *Ibid.*, LXII, p. 86 (1929).

Chemical analysis of some Indian Sands[1]

——	Patraghatta.	Naini.	Sankheda.	Pedhamli.	Fontainbleau for comparison.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
SiO_2 . .	96·00	98·95	99·39	98·10	99·80
TiO_2 . .	..	0·06	0·07	0·17	..
Al_2O_3 . .	1·15	0·39	0·11	0·84	0·13
Fe_2O_3 . .	trace	0·02	0·04	0·04	0·006
CaO . .	trace	0·11	0·15	0·15	trace
MgO . .	trace	*nil*	0·05	0·07	..
K_2O . .	2·85	0·08	*nil*	*nil*	..
Na_2O . .		0·02	*nil*	*nil*	..
Loss on ignition. . .		0·36	0·20	0·63	0·18
	100·00	99·99	100·01	100·00	100·116
Mechanical analysis—percentage over 0·25 mm. and under 0·5 mm.	..	91·1	70·7	65·4	..

The sands obtainable from Loghra (Lohagara Hill) and Borgarh (Bargarh) are in actual use by glass-making firms at Bahjoi, Moradabad district; Talegaon Dabhade, Poona district; Balawali, Bijnor district; and near Allahabad. In addition sands from Jejon Doaba (Jaijon Doaba) in the Hoshiarpur district and from Sawai Madhopur in Jaipur State are used by certain firms.

Amongst other raw materials used in glass manufacture mention may be made of sodium oxide either in the form of sodium carbonate (soda ash) or sodium sulphate (salt cake). The soda content in the batch mixtures in use in India is higher than the average. This high soda content will result in a glass of low melting point and thus one that is easy to work. Sodium sulphate is produced in India, as a by-product, in fairly large quantities. The soda ash used by

[1] Bull. Indian Ind. and Labour No. 29, p. 12.

many manufacturers in India is exclusively imported and supplies are obtained from Imperial Chemical Industries, Ltd. Saltpetre has been collected for years in Bihar, the Punjab, and the United Provinces and exported in large quantities from India. Glass-making firms obtain supplies of this ingredient from Jalesar district, Agra, Muttra, and Lahore. Calcium oxide is usually added in the form of the carbonate, limestone. Limestone of good quality occurs in various parts of India and is obtainable almost anywhere. Katni and Dehra Dun are two localities from which supplies for glass-making are obtained.

Some batch mixtures in use in India.[1]

Material.	1	2	3	4	5	6	7	8	9
Sand . .	100	100	100	100	100	100	100	100	100
Soda . .	0	50	40	2	50	43	33	48·5	53
Lime . .	10	10	12	20	15	8	16	16	12·5
Saltpetre .	..	..	2	..	4	11·5	2	6	10·5
Cullet . .	..	..	..	..	50	195	..	..	..

Cullet is merely another name for broken or waste glass.

Minor raw materials used in the industry include boric oxide used only for very special optical glass; and one per cent. of borax greatly improves the resistance of lead tableware glass to corrosion by water. The borax used by Indian glass-making firms is all imported either from Europe or Tibet; it is brought down to the plains of India from Ladakh and Western Tibet. Various colouring agents are used of which the more important are pyrolusite an oxide of manganese, nickel oxide, selenium and salts of chromium. The first three are also used as decolorisers, the action depending on superposing one tinge of colour, due to impurities, with an equal depth of a complimentary colour. Manganese dioxide used by Indian manufacturers is largely obtained from the Central Provinces, though material of the requisite purity is also obtained in the Pani mine, Chhota Udepur State.

There are certain raw materials consumed in the glass-making industry that are not included in the actual composition of the glass. These include refractory materials for the furnaces and most im-

[1] Indian Munitions Board. Industrial Handbook, 1919, p. 268.

portant of all coal for firing the furnaces. The sources of these materials may be seen by reference to the appropriate section of this review and it may be mentioned in passing that the cost of fuel constitutes one of, if not the, greatest items in the industry and hence a cheap supply of fuel is of paramount importance.

The choice of the raw materials for glass manufacture is a matter of great importance as the quality of the finished product depends very largely on the purity of the raw materials used. Suitable materials are available in India, so far as the major ingredients are concerned, and one of the most important considerations is that of the location of the factory so that these materials may be brought together with the minimum of expenditure on transport.

Impurities.

The impurities that may be harmful in glass-making are mainly those that may be present in the sand used. Alumina may be useful in glass that has to withstand pressure and heat as in thermometers, ampules, gauge glasses, combustion tubing, etc., as it reduces the coefficient of expansion and increases the hardness, brilliancy, and tenacity. Its disadvantages in glass manufacture are that (*a*) it decreases the fusibility (*b*) when present in excess of 3 per cent. it appreciably increases the viscosity at working temperatures (*c*) glasses with alumina do not readily mix with others so that it cannot be used for cullet (*d*) where salt cake is used and alumina is present there is a tendency to a slightly blue colour on account of the formation of an aluminium compound similar to ultramarine. If the alumina occurs as muscovite or clay it can be removed by washing the sand, but if it occurs as felspar it cannot be so removed.

Iron compounds occur as films coating the quartz grains or in particles of ilmenite or magnetite. If no decoloriser is used 0·02 per cent. or less of ferric oxide gives a colourless glass, the colour increasing to dark green with from 1 to 1·5 per cent. If decolorisers such as manganese dioxide, nickel oxide, or selenium can be used a higher proportion of iron is permissible. Magnesia is undesirable as it makes the glass viscous and 'stringy'. Organic matter in the sand chars when the batch is heated causing black spots that are not easily burnt out.

In addition to the manufacture of glass by modern methods there has, for a long time past, been an indigenous industry in the manufacture of the inferior varities of glass, used for making coloured bangles, from the impure sands of the rivers and the efflor-

escent alkali salts, known as *reh*, so common in many parts of India. In some cases there is a local industry in making bangles from lump glass bought from glass-making factories and melted up again for manufacture into bangles.

The value of the imports of glass-ware during the period 1924-28, is shown in Table 127. It will be seen from this table that imports of glass bangles constitute the largest item under one heading, though there has been a considerable diminution in the value of imports under this head. It is possible that this drop in total value is due as much to falling prices as to any reduction of imports due to competition from indigenous products. The average value of the glass-ware imports for the period 1914-18, was Rs. 1,30,80,795 and there was a very considerable increase during the next period 1919-23, when the average rose to Rs. 2,46,92,330. During the period under review, 1924-28, the average was Rs. 2,56,03,950 marking only a slight increase over the previous period. As the returns relate to value it is probable that a portion of the natural increase in consumption has been masked by a fall in prices. Nevertheless the figures do suggest that much of the additional consumption of glassware each year is now supplied by local factories, for which no returns of output are available. From the meagre evidence on the subject it appears that the glass-making firms now operating are firmly established and a gradual diminution in imports of glassware may be looked for in the future. The size of the potential market is evident from the figures quoted.

Table 128 shows the country of origin of the imports excluding those on Government account. This table is particularly interesting when compared with the returns for 1919. In that year Japan supplied over 65 per cent. by value, of the total imports; the United Kingdom supplied almost 20 per cent. whilst Belgium, Austria Hungary, and Italy supplied between 1 and 2 per cent. each. These figures show the extent to which the Indian glassware trade, particularly in glass bangles and beads, had been captured, during the war, by Japan. Turning to the recent figures it is at once apparent that much of the old trade of Austria-Hungary has been recaptured so that now Austria and Czechoslovakia supply between 27 and 28 per cent. by value, of the imports and almost precisely this amount of the trade has been lost by Japan, which now supplies only 26½ per cent. by value, of the imports. The United Kingdom now supplies only 10·per cent. whilst Belgium supplies an equal amount and Italy

just under 3 per cent. Germany has also regained a hold on the Indian market and imports from this source now constitute 17 per cent. by value, of the whole.

TABLE 127.—*Value of imports of Glass and Glassware.*

	1924	1925	1926	1927	1928
	Rs.	Rs.	Rs.	Rs.	Rs.
Bangles	95,33,673	1,01,43,994	93,97,403	83,00,875	79,98,056
Beads and false pearls	40,00,050	34,76,501	32,99,579	24,95 726	33,08,510
Bottles and phials	32,59 901	36,38,217	38,17,082	35,62,104	35,91,317
Funnels, globes, and glass parts of lamps	17,07,505	15,41,369	17,60,193	22,35,339	18,70,468
Scientific glassware	1,86,358	2,46,003	2,73,869	1,78,104	1,71,040
Sheet and plate	35,49,371	26,79,294	31,85,427	29,40,026	30,57,559
Tableware (including decanters, etc.)	9,46,730	9,58,869	9,05,402	8,91,304	11,40,252
Other glassware	25,82,436	25,87,160	34,35,014	35,34,692	34,82,909
Government imports	4,05,049	4,48,284	4,72,619	4,15,377	3,43,772
TOTAL	2,62,31,073	2,57,19,691	2,65,46,648	2,45,48,547	2,49,73,7[illegible]0

TABLE 128.—*Value of imports of Glassware according to country of origin, excluding Government imports*

	1924	1925	1926	1927	1928
	Rs.	Rs.	Rs.	Rs.	Rs.
United Kingdom	29,97,470	25,69,664	26,13,939	24,51,066	20,95,924
Germany	36,36,708	39,65,236	47,82,218	50,63,938	42,77,742
Belgium	27,40,180	21,86,981	27,21,087	23,84,355	25,36,341
Austria	5,15,010	2,96,018	3,82,285	3,84,912	5,26,708
Czechoslovakia	67,61,423	77,58,686	79,14,677	54,99,219	60,57,207
Italy	9,08,732	8,56,700	6,11,704	5,48,222	6,65,154
Japan	71,55,001	67,97,968	61,66,980	68,26,370	70,79,721
Other countries	11,11,505	8,40,154	8,81,139	10,55,088	13,91,220
TOTAL	2,58,26,029	2,52,71,407	2,60,74,029	2,41,33,170	2,46,30,017

Gypsum.

[E. H. PASCOE.]

Occurrence.

Gypsum occurs in considerable abundance in various parts of India, occurring both in the fibrous form and as clear selenite crystals. In Baluchistan, the Tertiary clays, and shales of all ages, whenever they are but slightly disturbed, contain numerous crystals of gypsum scattered throughout their mass[1]; in Sind it occurs in beds sometimes 3 to 4 feet thick near the top of the Gaj beds of the Khirthar range; in Kachh it occurs in abundance in the rocks below the Nummulitic limestones; in the Salt Range it occurs in large masses with the salt marl which lies underneath Cambrian beds but is possibly of Tertiary age; along the foot of the Kala Chitta range in the Rawalpindi and Attock districts, it is characteristic of the Upper Nummulitic stage, reaching thicknesses of two or three feet locally[2]. This mineral is especially characteristic of the Lower Tertiary of north-western India, and is plentiful in the Pegu beds of Burma in the transparent form of selenite[3].

A very interesting and, judging of the returns, comparatively important occurrence is one N.N.W. of Nagaur in Jodhpur (Marwar), Rajputana, where a bed, 5 feet thick or more, occurs in silt probably formed in an old salt-lake. The output from Jodhpur during the five years 1924 to 1928, was more than it was during the previous period, and is shown in Table 129. The increase in the value during the last seven years was a result of increased cost of extraction, due to labour difficulties, combined with an improved demand. The largest production of gypsum, as formerly, is still obtained from Jamsar in Bikaner, Rajputana (see Table 129), the average annual output during the quinquennial period under review being 25,566 tons, and the average value per ton working out at Rs. 2-5-6. An analysis in the laboratory of the Geological Survey of India shewed

	Per cent.
SiO_2	1·20
$Fe_2O_3+Al_2O_3$	0·48
CaO	32·39
MgO	0·48
SO_3	44·14
H_2O (combined)	20·16
CO_2	0·86
	99·71

[1] E. Vredenburg; *Rec. Geol. Surv. Ind.*, XXXVIII, p. 209 (1909).
[2] Pascoe; *Mem. Geol. Sur. Ind.*, XL, 375 (1920).
[3] *Ibid.*, 216 (1912).

TABLE 129.—*Production of Gypsum in India during the years 1924 to 1928.*

—	1924		1925		1926		1927		1928	
	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*
	Tons	*Rs.*	Tons	*Rs.*	Tons	*Rs.*	Tons	*Rs.*	Tons	*Rs.*
Baroda State	..	..	..	..	..	..	..	..	257	*1,631*
Kashmir State	48	*600*	132	*275*	121	*677*	..	..	82	*86*
Punjab—										
Jhelum	4,927	*4,927*	1,688	*3,411*	1,337	*3,008*	4,112	*7,065*	17,971	*28,848*
Rajputana—										
Bikaner	26,625	*55,851*	26,804	*57,784*	24,892	*55,937*	23,837	*54,991*	25,597	*74,873*
Jaisalmer	125	*823*	120	*800*	123	*825*	156	*1,003*	143	*859*
Jodhpur	6,325	*14,637*	7,500	*15,000*	8,000	*19,000*	10,000	*26,750*	15,000	*40,125*
TOTAL	38,123	*76,838*	36,244	*77,270*	34,473	*79,447*	38,105	*89,809*	59,050	*1,46,322*
Total value in sterling		*£5,527* (£1 = Rs. 13·9)	..	*£5,810* (£1 = Rs. 13·3)	..	*£5,929* (£1 = Rs. 13·4)	..	*£6,702* (£1 = Rs. 13·4)	..	*£10,919* (£1 = Rs. 13·4)

The quality is, therefore, good, and large quantities are available. Lesser quantities are available in many other places in Bikaner. Selenite crystals of similar origin to the deposit of Nagaur have been recently found in the *kankar* near the base of the silt in the Sambhar lake. A small gypsum deposit of no economic value occurs in the Chamba valley, Dholpur State[1].

Thick beds of gypsum are said to occur in the Kangra Chhu in Bhutan[2], in association with dolomites. The mineral is also known in limited quantities in the Older Alluvium, in the Hamirpur district, United Provinces[3], and under similar circumstances in the adjoining parts of the Jhansi district[4], where it is called *usraith*. Gypsum is also found in Spiti and Kanaur, in the Punjab Himalaya. Between the Lipak and Yuland rivers in Kanaur the gypsum occurs in immense masses and thick beds replacing Carboniferous limestone; it is used locally for whitewash, but the inaccessibility of the deposits would render abortive any attempt to mine the mineral for transmission to the Indian markets[5].

Uses.

The chief uses of gypsum are as a fertiliser for the soil and in the manufacture of Plaster of Paris. It also has the useful property of retarding the setting of any cement of which it forms an ingredient. Its effect in small quantities upon crops is said to be remarkable, and its usefulness to the monsoon crops of South Bihar has been experimentally demonstrated[6]. A common application is 2 maunds to the acre. Increasing amounts of gypsum are being imported by the Department of Agriculture, Bihar and Orissa, from the Jamsar quarries in Bikaner.

Since ancient times gypsum has been used in India as a plaster. Sir Aurel Stein in his work on Ancient Khotan records the fact that the whole of the stucco work discovered by him consisted very largely of Plaster of Paris, and that the figures and idols had in many instances been moulded by a process of *appliqué*. Moulding in Plaster of Paris is a modern art in India proper, and the ancient people of Khotan must have either discovered it spontaneously or derived their knowledge from some non-Indian race. Dr. Buist has

[1] A. M. Heron; *Rec. Geol. Surv. Ind.*, XLIV, p. 20 (1914).
[2] G. E. Pilgrim; *Ibid.*, XXXIV, p. 28 (1906).
[3] T. D. La Touche; *Ibid.*, XXXVII, pp. 281-285 (1909).
[4] C. A. Silberrad; *Ibid.*, XLII, p. 56 (1912).
[5] H. H. Hayden; *Mem. Geol. Surv. Ind.*, XXXVI, p. 101 (1904).
[6] D. Clouston; Review of Agricultural Operations in India, 1924-25, p. 52.

shown that the inhabitants of Sind have from ancient times practised the art of casting lattices and open-work screens for use in house construction, permitting the free circulation of air. The so-called 'stained glass windows' of the Marwaris are made by taking two lattice screens made of Plaster of Paris of identical pattern and fixing between them fragments of coloured glass so arranged as to bring out any purposed design. The pieces of glass are secured in position by a thin layer of liquid plaster applied before the two layers of lattice are brought together. The *shish* mosaic of Rajputana and the Punjab, of which the Shish Mahal at Agra, the Shish Maḥal at Lahore and the Shish Mahal at Amber near Jaipur are the best examples, is made by embedding pieces of glass silvered or backed with plated metal discs or coloured tinfoil within a plaster which consists mainly if not entirely of Plaster of Paris. This decadent form of art is, however, scarcely practised at the present day. The modern schools of art are responsible for the manufacture out of Plaster of Paris of figures, ornaments and toys; this industry has sprung up in India during the last few decades.

The largest producer of gypsum in the world is the United States of America, and the bulk of their output is used for the manufacture of fire-proof wall-boards. These have increased at the expense of the fibre-board on account of the ease with which they can be applied and by reason of economies effected by its use. The wall-board also lends itself to an attractive plastic finishing, which has added to its popularity. The resources of gypsum in India are large, and an increase in its use and demand would stimulate an industry capable of considerable expansion.

Kyanite (see also Sillimanite).

[J. A. DUNN.]

Of recent years the minerals kyanite and sillimanite have come into prominence because of their value for certain purposes in the ceramic industries. Their uses and properties will be found described under 'sillimanite'.

The known deposits of massive kyanite in India are confined almost entirely to Bihar and Orissa. In 1907, Mr. Srinivasa Rao submitted some specimens from Lapsa Buru in Kharsawan State, Singhbhum district, Bihar and Orissa, to Dr. L. L. Fermor of the

Geological Survey of India. They were then thought to be composed of corundum with some tremolite. In 1908, Dr. Fermor visited the hill and found considerable outcrops of kyanite-rock. Mr. K. A. K. Hallowes in unpublished departmental reports of 1907 and 1908, mentioned the occurrence of kyanite-bearing rocks in other parts of Singhbhum. During an examination of apatite deposits in the Mushabani-Badia tract, Dhalbhum, Dr. Fermor noticed adjacent outcrops of kyanite-quartz-rock in 1918. As massive kyanite was not then of economic value, these discoveries were not made public.

During the field season 1923-24, Dr. Dunn was in Kharsawan State continuing the larger survey of Singhbhum. The kyanite-rock was seen at the time and briefly described[1]. The first published note on the occurrence of kyanite in Singhbhum was in the Quinquennial Review of the Mineral Production of India, 1919-23. In 1922, the material was brought to the notice of Mr. P. Bosworth Smith, who furnished information later to the office of the Geological Survey. During the latter part of 1926 and early 1927, Dr. Dunn took up the examination of sillimanite and kyanite deposits in Northern India, and made a more thorough examination of the Singhbhum deposits.

In Singhbhum, kyanite-rock, associated with kyanite-quartz-rocks occurs at intervals along a belt of country nearly 70 miles in length, striking east from Lapsa Buru through the native states of Kharsawan and Seraikela, and turning south-east through Dhalbhum almost up to the Mayurbhanj border. The deposits strike parallel with the Singhbhum copper belt, occurring on the north and east (or hanging wall side) of the copper lodes. The main rock of this belt is aluminous muscovite-schist, but hornblende-schist frequently crops out. The mica-schist often contains large crystals of staurolite and garnet. The massive kyanite is usually associated with kyanite-quartz-rock or granulite.

At Lapsa Buru the kyanite-quartz-rock is found in enormous beds, the massive kyanite apparently occurring as segregations in the more acid rock. Some large deposits are, however, entirely of kyanite-rock. The pure kyanite-rock is massive, never cleaved; it is usually medium to coarse-grained, and even those rocks which, in the hand specimen, appear to be fine-grained, are found to consist under the microscope of quite coarse crystals full of fine inclusions. Kyanite is almost the sole constituent. It is often of the radiating

[1] J. A. Dunn; *Mem, Geol. Surv. Ind.*, LIV., p. 166 (1929).

columnar variety, and blades of crystals over 12 inches long may be seen sometimes in the large boulders. Such coarse kyanite indicates the action of at least a certain amount of metamorphic migration. Usually the only other constituent is rutile, which is often plentiful; fine corundum is present occasionally.

Other places at which massive kyanite occurs in workable amounts in Singhbhum are Ghagidih, Rakha Mines, Badia-Bakra and Kanyaluka. The minimum quantities of these present, calculated to a depth of 1 yard, are:—

	Tons.
Lapsa Buru	214,000
Ghagidih	20,000
Badia-Bakra	10,000
Kanyaluka	8,000

Analyses of typical specimens of these rocks are:—

	Lapsa Buru. Per cent.	Ghagidih. Per cent.
SiO_2	30·20	36·0
Al_2O_3	65·35	60·7
Fe_2O_3	3·19	2·3
TiO_2	0·76	1·2
CaO	trace	0·8
MgO	1·37	0·4
H_2O	0·61	0·9
	100·78	102·3

A certain amount of massive kyanite associated with blue corundum has been found at Rengadih in Manbhum, but it is of poor quality.

TABLE 130.—*Production of Kyanite during the years 1924 to 1928.*

—	1924		1925		1926		1927		1928	
	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*
	Tons	*Rs.*	Tons	*Rs.*	Tons	*Rs.*	Tons	*Rs.*	Tons	*Rs.*
Bihar and Orissa										
Kharsawan State	224	*3,360*	348	*2,058*	203	*1,221*	3,665	*23,517*	1,896	*12,166*
Manbhum .	..	..	2	*33*	..	..	..	..	..	.
Ghagidih . .	..	..	..	.	..	..	760	*7,600*	345	*5,17[illegible]*
TOTAL .	224	*3,360*	345	*3,091*	203	*1,221*	4,42[illegible]	*31,117*	2,241	*17,341*

Marble.

[E. H. Pascoe.]

Occurrence.

India has long been famous for its marbles, chiefly on account of the fine buildings, such as the Taj Mahal, built from this material by the Moghals. Amongst the remains recently found on the ancient site of Mohenjo-Daro in the Larkana district of Sind were shaped and dressed blocks of polished marble, many of them evidently for building purposes. The stone resembles that from Mekrana in Rajputana, whence we may imagine it to have been carried across the desert to the ancient city. Associated with these shaped blocks were found seals bearing a script having many resemblances to the Sumerian script of Mesopotamia. The marble quarries of north-western India, therefore, appear to have an antiquity which it would be difficult to rival. The best known occurrences of white marble are at Mekrana in Jodhpur, Kharwa in Ajmer, Maundla in Jaipur, Dadikur in Alwar, and Tonkra in Kishangarh, the last-named being dolomitic marble. It is to the coarseness of their grain that these marbles owe in part their resistance to the weather; it is their purity that enables them to maintain their white surface, and it is their translucence that gives them their delicate softness, which could never be obtained from a fine-grained marble more suitable for statuary than for architectural purposes. Similar white marble occurs in unlimited quantities forming the hills of Kyaukse, Sagyin and Mandalay, on the banks of the Irrawaddy. A coarse white marble is found in Mergui; whilst a saccharoidal dolomitic marble is exposed in large quantities at the far-famed Marble Rocks, forming a beautiful gorge traversed by the Narbada river near Jubbulpore. Marble has in the past been quarried in the Betul district of the Central Provinces.

Homogeneous yellow marble, and also yellow and grey shell marble, are found at Jaisalmer in Rajputana. Serpentinous limestones, showing green and yellow tints, are found in Ajmer and other places along the Aravalli belt; but the most striking example of this class occurs at Motipura in the Baroda state in the form of a handsome mottled green marble; a beautiful marble is obtained also at Sandara. A black marble taking a good polish, and other varieties, are found in Rewa Kantha, Rajpipla. Near the Narbada

river in the Indore state a fine coralline limestone, capable of a high polish, is quarried, and used in the construction of temples and palaces. Very variegated serpentinous limestones occur also in parts of the Cuddapah and Karnul formations in the Madras Presidency, and at several localities in the Nagpur and Chhindwara districts in the Central Provinces. Marble is plentiful in the Idar state. Pink marbles occur in abundance in the Aravalli belt of Rajputana, and in the Narsinghpur district of the Central Provinces. Mottled and streaked grey marbles occur in Jodhpur; dark-grey marbles are obtainable in Kishangarh and Jodhpur, while black marble has been found at Bhainslana in Jaipur. A mottled concretionary dolomitic marble occurs in the Vindhyan series in the Gwalior state, whilst onyx marbles are found at Nurpur in the Shahpur district, and near Jhuli in the Baluchistan desert.

Victoria Memorial.

Extensive tests made in the laboratory of the Geological Survey on the Mekrana marble [1] shewed that it is superior in many respects to the foreign marbles imported from Greece and Italy, and it was therefore employed in the construction of the Victoria Memorial in Calcutta. Messrs. Martin & Company, contractors for the building, opened up quarries at Mekrana and erected derricks for bringing the stones to the surface, as well as an extensive plant for cutting and dressing. Considerable difficulty was experienced at first in getting the required quantity of suitable material, but this was eventually overcome and a large supply of marble of great beauty made available. With the exception of European supervision the work at the quarries was done entirely by indigenous labour and the local artisans were trained to turn out carving of a high degree of excellence. Messrs. Martin & Company's operations at Mekrana during the quinquennium, 1914-18, produced a steady output averaging 3,500 tons a year. During the five years 1919-23, the average annual production was 6,649 tons, but the last two years witnessed a considerable decrease due to the fact that Messrs. Martin & Company ceased to work the stone. During the five-year period under review the annual output averaged 4,354 tons. This marble has been quarried for centuries.

[1] *Rec. Geol. Surv. Ind.*, XLVI, pp. 276-279. T. H. Holland; *Journal of the Queen Victoria Indian Memorial Fund*, No. II, March, 1904, pp. 18-26. *See also* General Report for 1913, *Rec. Geol. Surv. Ind.*, XLIV, p. 16 (1914).

TABLE 131.—*Production of Marble in India during the years 1924 to 1928.*

—	1924		1925		1926		1927		1928	
	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*
	Tons	*Rs.*	Tons	*Rs.*	Tons	*Rs.*	Tons	*Rs.*	Tons	*Rs.*
Rajputana—										
Alwar	1,150	*3,800*	600	*2,100*	936	*2,000*	902	*7,099*	223	*578*
Jaisalmer	131	*1,338*	120	*1,168*	80	*780*	238	*2,165*	631	*9,963*
Jodhpur	4,337	*1,70,348*	4,931	*1,93,132*	4,000	*1,12,000*	4,500	*1,26,000*	4,000	*1,12,000*
TOTAL	5,618	*1,75,486*	5,651	*1,96,400*	5,016	*1,14,780*	5,635	*1,35,264*	4,854	*1,22,541*
Tota value in sterling	..	*£12,625* (£1 = Rs. 13·9)	..	*£14,767* (£1 = Rs. 13·3)	..	*£8,566* (£1 = Rs. 13·4)	..	*£10,094* (£1 = Rs. 13·4)	..	*£9,145* (£1 = Rs. 13·4)

Marble used also to be quarried at the State Marble Works about 8 miles from Narnaul railway station, Patiala State, where an experimental marble plant was installed; during the period under review these works remained closed. There is also a small annual output of marble in the Mandalay district of Burma for images and pillars, but no figures of production are available. Table 131 shows the total reported production of marble in India between 1924 and 1928.

Imports.

In spite, however, of the existence of such large supplies of marbles of every variety in different parts of the Indian Empire, there is a large import of marble from abroad, chiefly from Italy and Greece. This is due partly to the great distances that separate the Indian marble deposits from such cities as Calcutta and Bombay, and partly to the systematic organisation of quarrying operations in Europe, by which the cost of foreign marble has been reduced. The foreign imports of 'stone and marble' during the five years 1924-28, averaged 6,090 tons a year, valued at Rs. 7,58,045, against 6,625 tons a year, valued at Rs. 7,74,939, during the previous quinquennium. The average annual value of the exports of 'stone and marble' was Rs. 60,999, against Rs. 1,22,776 for the preceding period. On account of the freight advantages attaching to the supply of European marbles, it would probably not pay to lay out much capital on Indian marble quarries; but, with an order sufficiently large to warrant systematic quarrying operations, marble ought to be procurable at a cost that would repay its employment locally in Rajputana, and possibly in Burma. The Rajputana quarries are both protected and hampered by their distance from the sea-board, but in Burma there are hills of marble standing on the banks of the Irrawaddy, and therefore well suited for water transport.

Mineral Paints.

[E. H. Pascoe.]

The manufacture of mineral paints is still very small in proportion to the demand and to the natural resources in apparently suitable minerals. In the Jubbulpore district the soft hæmatites of Jauli have been worked for red ochre and yellow ochre has been extracted in Panna State. The War gave a considerable impetus to indigenous paints, and works were set up in Mysore.

TABLE 132.—*Production of Ochre in India during the years 1924 to 1928.*

	1924		1925		1926		1927		1928		*Average.*	
	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*
	Tons	*Rs.*	Tons	*Rs.*	Tons	*Rs.*	Tons	*Rs.*	Tons	*Rs.*	Tons	*Rs.*
Bihar and Orissa	300	*7,665*	..	..	(a) 79	(b) *11,060*	..	..	..	..	76	*3,745*
Central India	4,378	*38,600*	4,101	*22,535*	806	*6,301*	760	*2,822*	3,499	*26,878*	2,709	*19,427*
Central Provinces	184	*2,698*	119	*2,410*	75	*1,500*	1,026	*9,533*	847	*7,915*	450	*4,811*
Gwalior	783	*10,571*	230	*4,937*	323	*6,937*	316	*4,162*	817	*10,252*	494	*7,372*
Madras	325	*4,375*	340	*4,600*	275	*3,750*	350	*4,750*	325	*4,500*	323	*4,395*
Rajputana	312	*650*	304	*621*	314	*629*	323	*721*	317	*688*	314	*662*
United Provinces	..	..	..	..	..	..	697	*5,439*	348	*2,742*	209	*1,646*
TOTAL	**6,282**	*64,559*	**5,094**	*35,103*	**1,872**	*30,177*	**3,472**	*27,477*	**6,153**	*52,975*	**4,575**	*42,058*
Total value in sterling	..	*£4,644* (£1 = Rs. 13·9)	..	*£2,639* (£1 = Rs. 13·3)	..	*£2,252* (£1 = Rs. 13·4)	..	*£2,051* (£1 = Rs. 13·4)	..	*£3,953* (£1 = Rs. 13·4)	..	*£3,108*

(a) Washed ochre.
(b) Value of washed ochre.

Such figures as are available are summarised in Table 132, in which the values are mostly much understated, being usually the rental or royalty paid. The Central Indian production is derived mainly from Panna and Sohawal; the mines in the former state are being worked at present by Messrs. The Olpherts Paints and Products, Limited, and Messrs. Turner Morrison and Company, both of Calcutta, and by Messrs. Abdul Sattar & Sons. The production in the Central Provinces is due mainly to the operations of the mines in the Jubbulpore district.

Gwalior was separated from the Central India Agency in 1920; the statistics relating to that state have therefore been shown separately in Table 132. The mines in this state at Behat in the Gird district are at present leased by Dhani Ram and The Rajputana Mineral Company, Limited. There was a small output of ochre in Bihar and Orissa from the Singhbhum and Puri districts. A small output of red ochre is reported from Hanamkonda in Hyderabad State.

Ochres, red, yellow, and of other colours, are commonly used by Indians in many parts of the country, in a crude or simply levigated form, under the generic name, *geru*. A common source of supply is laterite in the Peninsula and Burma, but well-defined ochres occur in deposits of various geological ages down to the Archæan hæmatites. In the Trichinopoly district yellow ochre is obtained from the Cretaceous rocks, and in Burma deposits are known among the Tertiary beds of the Myingyan district. It is also probable that various grades of ochre, umber and sienna could be set aside from the 'country' when working the Vizagapatam manganese-ore deposits. A black slate near Kishangarh has been successfully tried on the Rajputana-Malwa railway.

Mineral waters.

[W. A. K. Christie.]

Mineral waters do not have the same vogue in India as in many other countries, where table or medicinal waters, 'bottled at the source', find a ready sale. This is partly due to the greater respect generally shown in India for the *genius loci*—recognised as no more transportable than that of Lourdes; many of the springs in India are resorts of pilgrimage for countless worshippers, although their waters have no sale.

India possesses a great abundance of mineral springs, very many of them hot. A *Catalogue of the Hot Springs of India*, 301 of them, was compiled by T. and R. D. Oldham[1] primarily in connection with earthquake and *quasi*-volcanic phenomena. A list of the springs reputed to possess some medicinal value or charged with mineral matter has been prepared by T. H. D. La Touche[2] under the heading mineral waters.

An investigation into the radio-activity of the thermal springs of the Bombay and Madras Presidencies was undertaken by the Reverend Dr. A. Steichen and the Reverend H. Sierp, of St. Xavier's College, Bombay. The results of these two observers were published in two papers in the Indian Medical Gazette, Vols. XLVI and XLVII (December 1911 and December 1912). The springs at Tuwa on the line from Cambay to Godhra (Panch Mahals) were found to possess unusually high radio-active properties. Comparatively large emanations were found at Vajrabai and Unei. Principal Sierp has also published data for springs in the Thana district of Bombay, in Sind, and in Baluchistan [*Loc. cit.*, Vol. XLVIII, p. 259 (1913)].

Dr. L. L. Fermor, in his 'Mineral Resources of Bihar and Orissa' (*Rec. Geol. Surv. Ind.*, Vol. LIII, 290, 1921) has discussed the geological mode of occurrence of the springs of that province as a guide to geological enquiry and to those who may wish to turn some of them to commercial account.

Nickel.

[E. H. PASCOE.]

Ores of nickel (nickeliferous pyrrhotite) have been found amongst the copper-ores of Khetri and other places in Rajputana. Nickel has also been detected in small quantities in chalcopyrite and pyrrhotite found associated with the gold-quartz reefs of Kolar, and in pyrite said to be from the Henzada district of Burma.

Complex sulphide ores, consisting of pyrrhotite, pyrite, chalcopyrite, and molybdenite, have been received from the Tovala *taluk* in South Travancore. Both nickel and cobalt are present in quantities beyond mere traces, but nothing is yet known as to the extent of the deposits, nor have any proper average samples been assayed. A surface sample of ore showed 1·20 per cent. of copper, 0·64 per

[1] *Mem. Geol. Surv. Ind.*, Vol. XIX, Part 2 (1883).
[2] *Annotated Index of Minerals of Economic Value*, Calcutta, 1918.

cent. of nickel, and 0·08 per cent. of cobalt, with 12 grains per ton of gold and 2 dwts. 12 grs. per ton of silver. Further investigations might show that the deposits are richer than is indicated by this analysis.

On the 1st August, 1907, the issue to the public was commenced of the new 1-anna nickel coinage, consisting of an alloy of 25 parts of nickel with 75 of copper, leading to a further consumption of nickel. The consumption of nickel in India in the form of German-silver, has increased still further during the past fifteen years owing to the introduction of the 2-anna and 4-anna pieces: an 8-anna piece of the same alloy was put into circulation but has been withdrawn. The imports of nickel received at the Bombay Mint in 1919-20 and 1920-21, totalled more than 2,784 tons, valued at Rs. 85,74,038; those at the Calcutta Mint amounted to nearly 1,129 tons, valued at Rs. 34,65,234. No nickel was imported between the years 1921-22 and 1928-29.

As a by-product in the smelting operations of the Burma Corporation, Ltd., at Namtu, in the Northern Shan States, a regular production of nickel speiss was initiated in 1927, during which the quantity obtained amounted to 1,032 tons valued at Rs. 1,76,554 (£13,176); the speiss contained 24·64 per cent. of nickel, 15·92 per cent. of copper and also 33·58 oz. of silver to the ton. The production in 1928, rose to 2,933 tons, averaging 24·8 per cent. of nickel, 15·2 per cent. of copper and containing 32·2 oz. of silver to the ton; the value of the production in 1928, is estimated at Rs. 5,34,961 (£39,922). The speiss, which contains from 3 to 4 per cent. of cobalt, was shipped to Hamburg for further treatment.

Nickel is also a constituent of some importance in the copper-ores of Singhbhum in Bihar. At present it is being lost in the ore-dressing and smelting processes at Maubhandar. The introduction of an electrolytic plant would probably render the separation of the nickel an economic proposition.

Phosphates.

[E. H. Pascoe.]

Singhbhum district, Bihar and Orissa.

The double fluoride and ortho-phosphate of calcium—apatite—is known in many parts of India. Specimens of an apatite-magnetite rock from the two villages of Mosaboni (22° 31′; 80° 30′) and Patharghara ('Patholgora,' 22° 32′; 86° 29′) in Prince Mahomed Bakhtiyar

Shah's Dalbhum Estate, Singhbhum district, Bihar and Orissa, with patches of apatite sometimes up to ½ inch in diameter, led to further investigations. The phosphatic rock occurs as lenses in the Dharwar schists parallel to the strike, varying in size from 90 feet long by 24 feet thick in the middle, through lenses 2-3 feet by 1 foot, down to lenticles a few inches long, and finally to separate granules and crystals disseminated in the associated schists. The predominant mineral is usually apatite, but the quantity available has in some places not been estimated. Deposits have been located along a belt stretching for 12 miles in a direction roughly N. W. to S. E. from Pathargharа to Khejurdari and forming part of the Bengal Iron Co.'s concession for iron-ore. This belt is parallel and close to the Subarnarekha river and the Bengal-Nagpur railway, of which the nearest station is Ghatsila. A concession to work the apatite at Sungi ('Sunrgi,' 'Sonigi'), Kanyaluka and Badia in this belt was granted in the first place to the Great Indian Phosphates Co., Ltd., during the War. This Company subsequently went into liquidation, and the area was transferred to a private syndicate. In this concession an ore reserve between 100,000 and 200,000 tons has been estimated to occur. This ore averages 20-25 per cent. P_2O_5, with magnetite as the main gangue mineral; magnetic separation brings the grade up to about 35 per cent. P_2O_5. The deposit at Pathargharа is very similar in grade and gangue, and was at first worked as an iron-ore. The quantities of phosphatic rock despatched from the Sungi mine have varied capriciously, and in 1923-24, amounted to 3,406 tons. In 1924-25, 2,273 tons were despatched. During the following year the mines were not worked. The material was supplied to the Bengal Iron Co., but a hope has been expressed that it will be possible to produce ground phosphate suitable for fertilising purposes. Reserves of at least 250,000 tons of available phosphate ore are claimed to exist in this neighbourhood.

About 21 miles N. W. of Pathargharа, and evidently forming a continuation of the Khejurdari-Pathargharа belt is another locality at Nandup some 2½ miles south of Tatanagar railway station on the Tatanagar-Haludpukur branch line. Here the iron content is lower and quartz is often associated with the apatite. Around Chandar Buru several parallel zones occur. One of the northern zones in this vicinity has an average width of 50 feet of apatite with granite and mica-schist partings for a distance of 300 feet; of this two thirds consist of apatite. During the five years under review,

this area, which is being developed by Mr. E. O. Murray, supplied 7,100 tons of phosphate for agricultural purposes and 7,600 tons to the iron trades. Of the two types of deposit found in this area one has a gangue of iron ore and schist, and the other a gangue of quartz and schist; the average grade of the former is at present about 17 per cent. and of the latter 22 per cent. P_2O_5, but both show improvement with depth. The lower-grade material is too poor for the fertiliser market, which requires over 23 per cent. P_2O_5, but a froth-flotation experiment brought the percentage of P_2O_5. up to 30-35. Concentration with the aid of a magnetic separator is limited, owing to the fact that in this case the iron ore associated with the apatite is mainly haematite. The lower grade phosphate was being utilised by the iron trade, but, owing to the slump in the latter, it was not being worked towards the end of the quinquennium under consideration. In this area the reserves of phosphatic ore, of an average grade between 20 and 25 per cent. P_2O_5 are at least 250,000 tons; this is probably a minimum figure, as the deposits are not yet wholly uncovered.

There are other deposits which, it is thought, could be utilised if the demand increased. If quantity were required, Tata's Bessemer slag—whose contents average about 10 per cent. P_2O_5- could be mixed with the higher grade Nandup ore to give a 20 per cent. product. With the help of concentration plants and slag mixing it should be possible to produce at least 20,000 tons of phosphate suitable for fertilising purposes annually.

In the Nandup area the production of phosphate rock during the five years 1924-28, averaged 1,722 tons annually, valued at Rs. 28,474. Prospecting operations appear to have been commenced in Singhbhum in 1918.

Trichinopoly, Madras.

At a certain horizon about the middle of the Cretaceous beds in the Perambular *taluk*, Trichinopoly district, Madras, Warth noticed in 1893, a wholesale conversion of fossil shells into phosphate, or rather the production of interior casts of shells consisting of a black material rich in phosphate of lime. The same stratum also contains numerous light brown concretions of irregular shape and strongly phosphatic. The bed, which stretches for a distance of at least 10 miles, with an average dip of 12°, is exposed in a low ridge to the east of Valudayur[1]

[1] *Rec. Geol. Surv. Ind.*, XXVIII, pp. 17-18 (1895).

(11° 58′ 30″; 79° 46′) and was estimated to contain, within a depth of 200 feet, nodules to the amount of 8 million tons. The nodules containing from 56 to 59 per cent. of phosphate of lime with about 16 per cent. of the carbonate, are, however, distributed irregularly, varying between 27 and 47 lbs. per 100 cubic feet in excavations and 70 lbs. per 100 cubic feet in shallow workings. Attempts were made to utilise these phosphates in a finely powdered form as a fertiliser on the coffee plantations of Southern India, but the project was found to be unremunerative, and mining leases were consequently not taken out. Subsequent efforts to export the crushed nodules to Ceylon, where there was said to be a considerable demand for such material, were also unsuccessful. This may be looked upon as one of the two principal phosphate deposits in India, but the sparse distribution of the nodules and their high calcium carbonate content are factors to be considered in any attempt to manufacture super-phosphate. With a greater demand some use could probably be made of these deposits.

Mica mines, Hazaribagh, Bihar and Orissa.

Apatite is an abundant constituent of the mica-bearing pegmatites in the Hazaribagh district of Bihar and Orissa. Sir Thomas Holland considered that it might be possible to utilise the phosphatic mineral met with in the winning of mica. As an experiment 100 lbs. of the phosphatic material containing 82·5 per cent. of apatite, *i.e.*, 76 per cent. of phosphate of lime, was collected by three boys in 7 working hours from the fresh waste heaps at the Lakamandwa mine near Kodarma. Sir Thomas Holland remarks that 'a much larger quantity might have been obtained if the boys had been practised previously in recognising the material and still more if the mud and soft mica films which coated the apatite had been washed from the waste heaps.'[1] In the above-mentioned mine even the schists surrounding the pegmatite vein were impregnated with phosphate of lime. The phosphate in the Kodarma mica area is not a sufficiently abundant constituent of the rocks to warrant mining for it alone, but there seems little doubt that the exploitation of the waste dumps of the mica mines would establish a small but remunerative industry. Sir Thomas Holland's experiment showed that the value of the phosphate obtained would more than cover the cost of labour, packing, freight to Calcutta and royalty charges.

[1] *Mem. Geol. Surv. Ind.*, XXXIV, pp. 50-51 (1901).

Mica mines, Nellore district, Madras.

As in the mica industry of Bihar and Orissa, so in that of the Nellore district of Madras, apatite forms one of the prominent accessory minerals of the mica-bearing pegmatites, and is thrown away in the waste dumps. A careful examination of these dumps seems well worth while and might lead to a small phosphate industry.

Giridih and Raniganj.

The mica-peridiotite dykes in the Giridih and Raniganj coalfields of the Hazaribagh district, Bihar and Orissa, were found by Sir Thomas Holland on examination to contain an unusually high proportion of apatite. The analysis of two types showed the presence of 11·43 and 10·66 per cent. of calcium phosphate. The quantity is too small to warrant raising for economic purposes, the material comparing unfavourably with the basic Bessemer slags, but, as Sir Thomas Holland remarks, 'the decomposition of large quantities of this rock at the surface must contribute sensibly to the fertility of the neighbouring soil'.[1]

Rewa Kantha.

At Jothvad in the Narukot state of the Rewa Kantha Agency, Bombay, are manganese-bearing rocks in which Dr. Fermor found apatite to be so plentiful as to constitute in some cases 25 to 30 per cent. of the rock. The material is described as of no value for the winning of manganese.[2] It is doubtful whether it is worth treatment for the concentration of the phosphate, but the question as to whether the crushed rock could be used as it is for fertilising purposes, is perhaps worth investigation.

Vizagapatam.

In the Vizagapatam district of Madras apatite is a universal constituent of the rocks of the kodurite series, and may often be extracted in great abundance from the lithomarge resulting from the decomposition of the felspar in these rocks. At the manganese mines of Garbham (18° 22′; 83° 31′), Rawabhadrapuram (18° 30′; 83° 20′ 30″) and Devada (18° 15′; 83° 38′) it is especially abundant[3]. At Devada some hundredweights of deep sea-green apatite in rough prisms up to 5 inches in diameter were obtained.

[1] *Rec. Geol. Surv. Ind.*, XXVII, p. 135 (1894).
[2] *Mem. Geol. Surv. Ind.*, XXXVII, pp. 646-648 (1909)
[3] *Ibid.*, p. 251.

In the Dandot colliery (32° 39′ 30″; 73° 1′), Jhelum district, Punjab, shales overlying the coal seam were found to contain phosphatic nodules. The nodules contain about 65 per cent. of calcium phosphate, but their quantity was not considered sufficient for practical utilisation.

Jhelum district, Punjab.

Hayden remarks that the apatite schists, reported as occurring in the Dungarpur state of Rajputana, might perhaps be put to some use, but that the quantity available is unknown, the rocks being largely obscured by soil.

Rajputana.

In 1884, the discovery was announced[1] on the Midlands Estate at Mussoorie (30° 27′; 78° 8′), United Provinces, of nodules of phosphate of lime and layers of a phosphatic rock occurring in a shale band at the base of chert beds immediately overlying the Mussoorie limestone. The nodules, on analysis, were found to contain about 76 per cent. of calcium phosphate and the phosphatic rock about 66 per cent. of the same mineral. Both nodules and phosphatic rock vary considerably in constitution; some of the former are said to be devoid of phosphate. In spite of this, Mallet remarks that 'both substances, and especially the nodules, are of high standard as materials for the manufacture of artificial manure.'[2] Exposures of the deposit were found at three places in a length of a mile.

Mussoorie.

A blue earth was discovered about 1843, by Mr. F. Jenkins on the banks of the Dikhu river, above the town of Nazira (26° 55′; 94° 48′) in the Sibsagar district of Assam. Its blue colour was found to be due to the presence of the ortho-phosphate of iron, vivianite, $Fe_3(PO_4)_2$. Presumably the earth formed part of the alluvial deposits but the sources of the phosphate, which must lie further up the Dikhu valley, have never been explored.

Sibsagar district, Assam.

During a journey up to Khatmandu in Nepal in 1874, Medlicott records an extensive deposit of stiff blue-grey clay, in which he noticed blue specks of vivianite freely scattered throughout. This deposit is known for its fertilising properties, and is used as a manure throughout the valley. As Nepal is still tabooed to European investigators, except at the

Nepal.

[1] *Rec. Geol. Surv. Ind.*, XVII, pp. 198-199 (1884).
[2] *Ibid.*, XVIII, p. 126 (1885).

invitation of the Durbar, nothing further is known of this occurrence.

Gaya district, Bihar and Orissa.

Sir Thomas Holland mentions the occurrence of considerable masses of triplite—a phosphate and fluoride of iron and manganese, containing about 32 per cent. of phosphoric acid—in a mica mine two miles south-east of the village of Singar (24° 34′ 30″; 85° 33′ 30″) in the Gaya district of Bihar and Orissa. It was considered to be probably of small value as a source of phosphoric acid, but an output of 10 tons of the mineral during the year 1914, was recorded.

Export of Bones and Bone meal.

A regrettable feature in the economic history of India is the export of phosphate in the form of bones. Bone meal and other animal manures have been for some time, and still are, manufactured in Calcutta, but the want of a cheap supply of sulphuric acid has in the past prevented their treatment to form 'super-phosphate', the small quantity of the latter used in India being mostly imported from Europe. Sulphuric acid is now being produced on an appreciable scale in the country (*see* below), and a start has recently been made by Messrs. Parry & Co. at Ranipet, 60 miles from Madras, to manufacture superphosphate from crushed bones and sulphuric acid ('chamber acid') in high-pressure autoclaves. It is to be hoped others will follow this good example, since large quantities of bones and bone meal are still being exported. The continual export of bones and bone meal means a steady drain on India's supply of phosphate. The soil in many of the alluvial tracts may be rich enough in phosphates to remain, for the time being, not seriously impoverished by these exports, but the time must come when the depletion of phosphate, due to its removal in the form of bones and the different kinds of grain will make itself felt in the country.

The Chemical Section of the Agricultural Department at Pusa have demonstrated the value of dissolving the Bihar phosphate in perchloric acid and precipitating the phosphoric acid as lime phosphate. The latter contains about 35 per cent. of phosphoric acid, almost all of which is citrate-soluble.[1] The manurial value of this product is said to be equal to that of superphosphate, but whether the process can be employed successfully on a commercial scale remains to be seen.

[1] D. Clouston. Review of Agricultural Operations in India, 1924-25, p. 55.

The export of bones, which had fallen excessively during the War, rose immediately afterwards and exceeded 108,000 tons in 1920. The total exports of manures, including bones and bone meal, from India during the calendar years 1924-1928, are given in the following table. From this it will be seen that over three-fourths of the total represent crushed and uncrushed bones and bone meal. The imports of bones into India are negligible in quantity. Most of the bones and bone meal exported during the five years under review were sent to Belgium, Ceylon, Japan, France and the United States.

TABLE 133.—*Export of Manures from India during the years 1924 to 1928.*

—	1924	1925	1926	1927	1928
	Tons.	Tons.	Tons.	Tons.	Tons.
Bones—					
Crushed	44,867	41,702	51,633	57,208	57,512
Uncrushed . . .	291	502	498	356	224
Bone meal . . .	35,169	38,363	45,706	40,090	34,313
Total of bones .	80,327	80,567	97,837	97,654	92,049
Fish manures and guano .	24,671	11,359	8,697	7,953	10,590
Sulphate of ammonia .	8,884	8,376	1,309	6,748	13
Other kinds . . .	1,981	4,502	7,440	7,691	12,902
Total of manures including bones.	115,863	104,804	115,283	120,046	115,554

Basic Slag.

Basic slag, formed in the production of steel, contains phosphate usually in sufficient quantities to make the ground material of value as a fertiliser. The substance is hard and the grinding expensive, so that unless a sufficient proportion of phosphoric acid is present, the preparation of the powdered fertiliser would be unremunerative. Indian basic slag is said to be poor in phosphorus, but, by mixture with some of the Indian apatite, which contains too much iron for superphosphate manufacture, a utilisable fertiliser can be obtained.

The only company manufacturing steel on a large scale in India to-day is the Tata Iron and Steel Company at Jamshedpur. The small steel works at the Government Metal and Steel Factory, Ishapore, at the East Indian Railway Works, Jamalpur, at the Bombay, Baroda and Central India Railway Works, Ajmer, at the Ballygunge Works of the Hukumchand Company, Calcutta, and at the works of the Kumardhubi Engineering Company, produce altogether less than 5 per cent. of the Tata Company's output, and were brought into existence to meet special requirements. At Jamshedpur seven open-hearth furnaces are in use, four of 50-55 tons capacity and three of 60-65 tons capacity; 218,472 tons of steel were manufactured in 1924, 309,938 tons in 1925, 360,980 tons in 1926, 414,738 tons in 1927, and 289,865 tons in 1928. Their basic slag varies considerably in its phosphorus contents but averages about 10 per cent. P_2O_5; the output is some 40,000 tons annually (about 250-300 lbs. of slag per ton of finished steel). A small quantity, it is understood, is used in bringing up the phosphorus contents to the requisite standard in the tin-plate industry; the rest is dumped to level up low-lying ground. The Indian Iron and Steel Company, when they manufactured steel, also found that their slag contained insufficient phosphorus to make it commercially attractive as a manure. The Bengal Iron Company no longer make steel and therefore do not produce basic slag.

Rare Minerals.

[W. A. K. Christie.]

This title is used for a somewhat miscellaneous lot of minerals which do not fall conveniently under other heads. They are arranged as in Dana's Mineralogy. The adjective 'rare' should not be taken too literally—rutile, for instance, is a commoner mineral than cassiterite, although it finds an appropriate place here. Most of these minerals occur in pegmatites in the Archæan rocks of Peninsular India. None of them is known to occur in quantities sufficient to justify extensive exploitation.

Platinum and Iridosmine.—Platinum and iridosmine have been found in the auriferous gravels of the rivers draining the slopes of the Patkoi ranges, both on the Burma and the Assam sides. The former metal used to be obtained, with gold, by the Burma

Gold Dredging Company from the gravels of the Irrawaddy above Myitkyina. This company went into liquidation in 1918, and since that time no platinum has been produced in India.

Molybdenite, the sulphide of molybdenum, occurs in Tavoy as—

(*a*) an accessory mineral in the granite,
(*b*) in greisens bordering cassiterite and wolfram veins,
(*c*) in quartz veins with cassiterite and wolfram,
(*d*) in pegmatites with wolfram, cassiterite and sometimes scheelite,
(*e*) in veins with sulphides and entire exclusion of cassiterite and wolfram.

The mineral is widely distributed but of more frequent occurrence in or about veins in granite than in those enclosed by sedimentary rocks. It is especially abundant in the Wagon region, at Kyaukanya and at Sonsin, which furnishes the only known occurrence of type (*e*). No attempts have been made, in spite of the high value of the mineral, to recover it by scientific processes, and, owing to its flakiness, it is not recoverable by the primitive processes of 'cobbing and panning' so prevalent in the field. The small quantities which have been exported were obtained by laboriously picking out the larger flakes by hand from the quartz matrix. The Sonsin deposit is the most promising known at present but it is little more than a 'prospect'. Molybdenite was one of the first minerals to form in the Tavoy veins and is often found intergrown with mica on the walls.

Molybdenite occurs in the crystalline rocks and in quartz in various parts of Chota Nagpur. It has been reported from Cherrapunji, Assam, where it occurs in a microcline granite gneiss. It has been found as scattered scales in pegmatites intruded into the khondalite series near Kunaveram village in the Upper Godavari Agency, Madras. A similar mode of occurrence has also been noticed in the aplite and pegmatite veins traversing the schistose gneisses 1½ miles east of Karadikuttam in Retiambadi Mitta, west of Palni, Madura district, Madras. It occurs in an elæolite-sodalite-cancrinite pegmatite at Mandaoria, near Kishangarh, Rajputana, and has been found in a pegmatite cut through at a depth of 2,500 feet in the Balaghat lode, Ooregum, Kolar gold field, Mysore. Molybdenite occurs disseminated through the pyrrhotites of the Travancore state.

From Tavoy a total output of 7·5 cwts. valued at Rs. 1,407 was reported during the period 1919-1923, obtained in the course of wolfram mining operations. No production has been reported since.

The chief use of molybdenum is as a constituent of alloy steels. Almost all the world's supply of molybdenite is mined in the United States.

Ilmenite.—*See* page 109.

Rutile, one of the natural forms of titanium dioxide, is widely distributed throughout many of the crystalline schists. It has been found in pieces of some size during exploratory work for mica in the neighbourhood of Ghatasher in the Narnaul district of Patiala State, Punjab.[1] P. N. Bose also reports the occurrence of this mineral in the vicinity of Kadavur in the Trichinopoly district of Madras. J. A. Dunn[2] reports it as often plentiful in the kyanite rock of Lapsa Buru, Singhbhum, but its separation would be difficult. It occurs, too, in considerable quantities in the black sands of the Travancore coast (*see* under *Ilmenite*), from which it is recovered in the zircon fraction. After magnetic separation the zircon sand is said to contain about 12 per cent. of rutile. On account of the similarity of specific gravity of the two minerals its separation is a matter of some difficulty. Rutile is, of course, more suitable for the preparation of titanium dioxide paints than ilmenite, and at the end of 1928, was (in New York) 16 times its price.[3] Although the titania contained in bauxite is not present as the mineral rutile, attention may here be drawn to the fact that many Indian bauxites are rich in this oxide. When an aluminium industry is established in India, especially if the Bayer process be used, a new source of titania will be available in the by-product slimes.

Beryl, a silicate of beryllium and aluminium, occurs in the mica pegmatites of the Kodarma Forest area, of Nellore[4] and of Kishangarh. It is usually found close to the mica books on the flanks of quartz cores in the pegmatites, sometimes in crystals a foot long and six inches in diameter. In Kishangarh, on the slopes of the hills between Ajmer and Narwar, several tons of beryl crystals have weathered out from the pegmatites.

[1] *Rec. Geol. Surv. Ind.*, XXXIII, p. 59 (1906).
[2] *Mem. Geol. Surv. Ind.*, Vol. LII, p. 221 (1929).
[3] *Chem. Met. Eng.*, Vol. XXXVI, p. 127 (1929).
[4] Cf. V. S. Swaminathan, the Mode of Occurrence and Chemical Composition of Beryl from Nellore. *Trans. Min. Geol. Inst. Ind.*, Vol. XXII, p. 258 (1928).

Pure beryl contains only five per cent. of beryllium; the extraction of the metal is a laborious process and from 500 pounds of raw beryl only one pound of beryllium is recovered. The uses of the metal are still in the experimental stage. Small percentages of it in copper and nickel impart remarkable hardening properties on heat treatment of the alloys. In September, 1928, the price of beryl was 150 to 200 dollars per metric ton.[1]

Zircon.—*See* page 312.

Gadolinite, a silicate of yttrium, beryllium and iron, has been found in a tourmaline pegmatite, associated with cassiterite, at Hosaippura, in the Palanpur state, Bombay Presidency.

Allanite, a hydrous silicate of calcium, aluminium, iron and the rare earth metals, has been found in some of the pegmatites of the Nellore district (Sankara, Vadlapudi and Turpupundla) and near Palni, Madura district, Madras. In Bihar and Orissa it occurs near Bahea village, in the Ranchi district.

Sphene, titano-silicate of calcium, is a not uncommon accessory mineral in many of the crystalline rocks. A large and beautiful crystal of a variety containing a noticeable percentage of cerium earths was obtained by Dr. A. M. Heron at Dodikar, five miles W. of Alwar City in Rajputana, but its exact provenance is unknown.

Sipylite, a niobate of erbium and other rare earth metals occurs in association with samarskite. It has been found in a mica pegmatite about 3 miles to the north-west of Sankara and also in the Razulapad mica mine, both in the Nellore district.

Columbite-Tantalite, columbate and tantalate of iron and manganese, pass gradually from columbite, the nearly pure columbate to tantalite the nearly pure tantalate. The specific gravity changes correspondingly from 5·3 to 7·3. Indian occurrences are usually near the columbite end of the series.

The chief source of specimens is the mica-bearing pegmatites. Columbite is not uncommon in the Singar *zamindari*, Gaya district, where beautiful crystals have been obtained near the village of Pichhli[2]; also in the Kodarma Forest area of the Hazaribagh district. At Pananoa hill, Monghyr, Bihar, tantalite occurs as well as columbite. Two specimens sent to the Geological Survey Office have the high specific gravities of 6·75 and 6·92; assays have shown 37 and 52 per cent. of Ta_2O_5 respectively. Columbite also occurs

[1] *Chem. Trade Jour.*, Vol. LXXXIII, p. 270 (1928).
[2] G. H. Tipper; *Rec. Geol. Surv. Ind.*, L, pp. 260-261 (1919).

in the Madura, Nellore, Salem and Trichinopoly districts of the Madras Presidency; at Masti[1] in the Bangalore district and other places in the Mysore State[2]; in Kashmir, near Machial, 20 miles from the Padar sapphire mines.

Columbium has only recently been isolated in the pure state; it is said to have characteristics which may make it of real value.[3] Tantalum has been supplanted by tungsten as a material for electric lamp filaments. One of the main present uses of the metal is in connection with vacuum tubes for radio receiving and broadcasting, for Röntgen ray work, and for neon lights. Here it acts as an absorbent of gaseous impurities[4]. Western Australia is the main producer of tantalite.

Samarskite is a highly complex columbate and tantalate of metals of the cerium and yttrium groups, iron and uranium. It has been found in the Sankara mica mine (79° 47′; 14° 15′) Nellore district, Madras, where G. H. Tipper[5] reported the occurrence of masses weighing as much as 200 pounds. It has also been found in the same district at Tummalatalupur, near Jogipalli Shrotriem. It has been recorded from Yedur, Bangalore district, Mysore, and from Tavoy.

Æschynite, a titano-niobate of the cerium group of metals, has been identified from a pegmatite in the Eraniel *taluk*, Travancore State.

Xenotime, yttrium phosphate, has been reported from Aru Burru, Kanyaluka *mauza*, Bihar, where it is associated with the apatite deposits. Its optical characters are those of an orthorhombic mineral (xenotime is tetragonal) and G. H. Tipper[6] suggests that its cerium content is responsible for the discrepancy.

Pitch-blende.—Pitch-blende or uraninite with other uranium minerals has been found at two localities in the Singar *zamindari*, Gaya district, Bihar and Orissa. The occurrence at Abraki Pahar near the village of Bhanen Kap has been known for some years.[7] The chief mineral associated with the pitch-blende here is triplite, a phosphate of iron and manganese, in considerable quantities. Columbite and zircon also occur. The locality was visited by

[1] *Rec. Mysore Geol. Dept.*, III, p. 182 (1900-01).
[2] Mineral Resources of Mysore, p. 192.
[3] F. L. Hess; *Min. Res. U. S.*, 1927, part 1, p. 412.
[4] C. H. Jones; *Chem. Met. Eng.*, Vol. XXXVI, p. 551 (1929).
[5] *Rec. Geol. Surv. Ind.*, XLI, p. 271 (1912).
[6] *Ibid.*, LI, p. 31 (1921).
[7] T. H. Holland; *Mem. Geol. Surv. Ind.*, XXXIV, p 31 (1901).

the late Mr. R. C. Burton, who found that the pitch-blende occurs as nodules in the pegmatite, each nodule having an aureole of yellow uranium ochre.[1] A company was formed for the exploitation of this occurrence but it was liquidated in 1914. The prospecting work done did not show the presence of any large deposit. The second locality is near the village of Pichhli where the pitch-blende is found in a pegmatite in a similar way to the above. The associated minerals are monazite, apatite and columbite.[2]

Green and yellow incrustations containing uranium occur on the apatite-magnetite rock at Sungri, Dhalbhum, Bihar and Orissa.

Sillimanite.

[J. A. DUNN.]

It has been known for several years that 'sillimanite' was one of the dominant constituents of ceramic wares. This led to the realisation that the higher the raw materials were in Al_2O_3, *i.e.*, the nearer they approached the composition of sillimanite the more highly refractory would be the resulting products. This suggested to several investigators the use of sillimanite, $Al_2O_3 \cdot SiO_2$, in the actual mix. Large supplies not being available, the attempt was made in 1920 to manufacture artificial sillimanite. During 1924, Bowen & Greig showed that sillimanite could not be made artificially and that the true composition of the artificial 'sillimanite', found in all ceramic wares, was $3Al_2O_3 \cdot 2SiO_2$, which they called mullite. They then found that natural sillimanite itself breaks up into crystals of mullite above a temperature of 1,545°C. Later Greig found that, besides sillimanite, kyanite and andalusite also broke up into mullite with the concomitant formation of a siliceous glass (probably cristobalite) on heating above certain definite temperatures. Of the three minerals, kyanite alters at the lowest temperature, sillimanite at the highest. In the case of kyanite the change is accompanied by a considerable change in volume, but with andalusite and sillimanite the increase in volume is very small. Further investigations led to the conclusion that the mullite was the important material in aluminous refractories, and that this mullite could be derived either from kyanite or sillimanite. Owing to its

[1] *Rec. Geol. Surv. Ind.*, XLIV, p. 31 (1914).
[2] G. H. Tipper; *Ibid.*, L, pp. 259-261 (1919).

expansion on heating, kyanite could only be used after it had been converted in kilns to mullite, whereas sillimanite can be used immediately in the raw state. Ceramic materials and refractory bricks made from these materials possess the following properties: strength and toughness, high melting point (about 1,810°C.) and stability up to that temperature, low co-efficient of expansion, low electrical conductivity, freedom from volume changes, neutral re-action and resistivity to corrosive slags and to oxidising and reducing conditions.

To the ceramic industries mullite appears to have many uses, whether it be derived from sillimanite or kyanite. Electrical porcelains made from it are very tough and strong and have a very low conductivity. It has been used in sparking plugs. It is finding a wider use as a refractory brick where the furnace conditions are severe as in boiler furnaces, combustion chambers, and particularly in glass manufacture. It is not likely to find any application in such metallurgical processes where it would come in contact with metallic slags, as it fuses readily under the action of metallic oxides.

In India kyanite occurs mainly in Singhbhum, Bihar and Orissa, and sillimanite in Nongstoin State, Assam, and at Pipra in Rewah State, Central India. The mining future of these refractory materials in India seems to be dependent upon two factors, *viz.*, the favourable outlook with which the users may accept the materials, and the producer's ability to place them sufficiently cheaply on the market. At present the chief market is on the Continent, particularly Czecho-Slovakia. The price of sillimanite in England has fluctuated between £11 and £14 per ton. So far the market has not been impressed sufficiently to take up the use of the material whole-heartedly; and it would be advisable for the Indian producers concerned to sell at the minimum price in order to widen the market.

The occurrence of the deposits of sillimanite in Assam became known in a curious way. During the War a deposit of corundum was being mined by the Khasi Mines Company, at Sona Pahar, Nongstoin State, Assam. In 1921, Messrs. Pawle and Brelick, the agents for the company in England, found that the hardness of a consignment was very unsatisfactory and a chemical and microscopical examination was made by Messrs. G. T. Holloway of Limehouse. It was thought that the material was mainly sillimanite, which opinion was confirmed by Dr. C. S. Fox, Assistant Superintendent

of the Geological Survey of India, who was at that time attached to the Indian Trade Commissioner in London.

The occurrence of corundum in Assam was known to Mallet[1] in 1879, and other later investigators[2] have referred to the deposits. In order to clear up the relation of the sillimanite to corundum in these deposits, Dr. Dunn of the Geological Survey of India visited the area in December, 1926, and January, 1927. His descriptions of this deposit and other sillimanite and kyanite deposits in India have since been published.[3]

The deposits of sillimanite at Sona Pahar in Assam may be reached as follows: by motor lorry from Gauhati to Boko 36 miles to the west thence 12 miles south by bullock cart to Haima at the foot of the Khasi hills, and finally some 2 days' march south into the hills for 23 miles.

The area is on the Khasi plateau and the height above sea level about 3,000 feet. The sillimanite-corundum deposits are associated with such highly aluminous rocks as cordierite-biotite-quartz-microcline gneiss and sillimanite-quartz-schists. The majority of the deposits consist mainly of massive sillimanite with a little corundum; one or two are almost entirely of corundum and several are entirely of sillimanite. Impurities are not abundant and consist mainly of rutile, a very little biotite and some iron ore. There are some thirteen different known deposits, occurring over a belt about 3 miles long by 1 mile wide. In estimating the quantity of material available, it is difficult to arrive at any definite quantity owing to the peculiar mode of occurrence of the individual deposits, and to the fact that a very large amount of the material is completely decomposed. However, reckoning down to a depth of only 10 feet there is at least a total minimum quantity of 83,000 tons available. The actual quantity may be many times this amount. These deposits are, however, very unfavourably situated, and under present conditions transport charges would be high—about Rs. 56 per ton to the Brahmaputra river.

The deposit of corundum-sillimanite in Rewah State, Central India, is near Pipra, a small village in the extreme south-east of the state, about 5 miles from its eastern and southern boundaries. The

[1] F. R. Mallet; *Rec. Geol. Surv. Ind.*, Vol. XII, p. 172 (1879).
[2] F. E. Jackson; *Ibid.*, Vol. XXXVI, p. 323 (1908); *op. cit.*, Vol. LV, p. 27 (1924).
[3] J. A. Dunn; *Mem. Geol. Surv. Ind.*, Vol. LII (1929).

deposit is associated with sillimanite-schists and pyroxene-bearing rocks. The bed of corundum is about ½ mile long by about 70 yards wide. Reckoning on an average depth of 30 feet, the total quantity of corundum available is estimated to be 100,000 tons. Of sillimanite there is about 100,000 tons of good material, but the possibility of exploiting the better class sillimanite is limited, owing to its intimate admixture with impure material. This deposit also suffers from the disadvantage of high freight charges to Calcutta. At present the material is carried by bullock pack to Mirzapur, about 120 miles.

Other small unimportant deposits of corundum and sillimanite occur in the Bhandara district of the Central Provinces.

Recently sillimanite-rock has been found to occur in the southern end of Hsipaw State, Burma.

The following analyses are of typical sillimanite-rock from Assam and Rewa State.

	Assam.	Rewa.
	Per cent.	Per cent.
SiO_2	36·26	33·40
Al_2O_3	61·59	59·49
Fe_2O_3	1·26	0·94
TiO_2	0·15	0·19
CaO	trace	trace
MgO	0·16	0·039
Water	..	6·12
	99·42	100·67
Sp. Ex.	3·27	3·122

Slate.

[E. L. G. Clegg.]

Slate-quarrying gives a means of livelihood to numbers of workers along the outer Himalaya, where the foliated rocks, though often not true clay-slates, possess an even and perfect fissility, which enables them to be split for slabs and even fine roofing slates at Kanyara. In the Kangra district, at Kanyara, work is being carried on in a systematic manner by the Kangra Valley Slate Company, Limited, which, during the five years ending the 10th June, 1928, has declared dividends of 22 per cent. per annum. The same company work quarries in clay-slates amongst the Aravalli series

TABLE 134.—*Production of Slate during the years 1924 to 1928.*

	1924		1925		1926		1927		1928		AVERAGE.	
—	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*
	Tons	*Rs.*	Tons	*Rs.*	Tons	*Rs.*	Tons	*Rs.*	Tons	*Rs.*	Tons	*Rs.*
Bihar and Orissa— Monghyr	1,830	*28,208*	1,944	*30,980*	138	*5,845*	1,897	*35,932*	2,935	*68,707*	1,749	*33,934*
Singhbhum	1,448	*2,503*	164	*3,669*	187	*3,870*	32	*534*	..	..	366	*2,115*
Central India— Kothi	222	*110*	230	*448*	198	*735*	..	..	..	..	130	*258*
Kashmir	29	*700*	14	*179*	..	..	93	*340*	..	..	27	*244*
Madras— Kurnool	8	*15*	..	..	..	..	..	..	..	..	2	*3*
Mysore— Kadur	..	..	..	..	..	..	16	*1,400*	..	..	3	*280*
Punjab— Gurgaon	1,241	*22,654*	2,019	*23,462*	1,590	*23,725*	787	*14,863*	740	*15,040*	1,275	*19,949*
Kangra	5,840	*1,27,948*	4,771	*1,14,294*	4,465	*1,07,017*	4,218	*1,08,961*	4,110	*1,08,925*	4,681	*1,13,429*
Keonthal	..	..	..	..	..	..	..	..	278	*1,225*	56	*245*
Rajputana— Alwar	950	*2,000*	450	*1,125*	270	*1,900*	230	*970*	200	*830*	420	*1,361*
United Provinces— Almora	1,752	*6,751*	15,349	*8,597*	900	*3,961*	31	*803*	289	*1,392*	3,664	*4,300*
Banda	..	..	..	..	..	..	499	*6,607*	506	*7,650*	201	*2,851*
Garhwal	9	*27*	102	*202*	297	*579*	38	*77*	42	*81*	98	*193*
Naini Tal	71	*40*	..	..	135	*177*	..	..	51	*67*	51	*59*
TOTAL	13,400	*1,90,956*	25,043	*1,82,956*	8,180	*1,47,809*	7,841	*1,70,468*	9,151	*2,03,917*	12,728	*1,79,221*
Total value in sterling		*£13,737* (£1 = Rs. 13·9)	..	*£13,756* (£1 = Rs. 13·3)	..	*£11,031* (£1 = Rs. 13·4)	..	*£12,721* (£1 = Rs. 13·4)	..	*£15,218* (£1 = Rs. 13·4)	..	..

near Rewari in the Gurgaon district south of Delhi. There are in addition several smaller companies working slate in the Kangra and Gurgaon districts.

In the Kharakhpur hills, Monghyr district, Bihar, the properties held by Messrs. C. T. Ambler & Company were transferred to a limited company, Ambler's Slate and Stone Company, in 1913. During the period under review this company raised on an average 1,749 tons of slate annually. The slate worked is often slightly phyllitic and is probably of Dharwarian age ; it is now practically only used for terraced roofing. Enamelled slate slabs for electrical purposes and switch-boards and fuse bases are manufactured but the demand is very small as the slate is not as suitable as the Welsh slate for that purpose. Since the advent, four years ago, of cheap school slates from Germany made of thin sheet steel, blackened and stoved, their manufacture in India has been discontinued as it has been impossible to compete with the former. Competition from cheap aluminium and enamelled wares has also driven the small slate dishes and curry platters for native use off the market. Some of the quarries held by this company date back to ancient times, and probably yielded the very fine piece of slate from which the throne of the Nawabs Nazim of Bengal, now shown in the Indian Museum, was fashioned.

Slate of good quality and in considerable quantity was observed in the valley of the Tuzu river, some 25 miles east of Kohima, in the Naga Hills.[1] The locality is just within the borders of our administered territory, but is somewhat remote for present-day exploitation. It is used by the half-civilised local tribes for roofing, millstones and other purposes.

Slate is also being worked in various parts of the so-called transition series of rocks of the Peninsula ; such figures as are available to show the extent of the trade are given in Table 134 with the figures of production of the two companies already mentiond. From these it appears that the average annual output of slate during the quinquennium has been 12,723 tons valued at Rs. 1,79,221 against 37,887 tons valued at Rs. 1,78,187 during the previous period. This large decrease in tonnage, which is not reflected in the value, is accounted for by an average decrease of 9,652 tons of slate from Almora in the United Provinces. The decrease in average for Almora value works out at only Rs. 1,343.

[1] E. H. Pascoe; *Rec. Geol. Surv. Ind.*, XLII, p. 263 (1912).

Sodium Compounds (other than Salt).

[W. A. K. CHRISTIE.]

Besides sodium chloride, other salts of soda, notably the sulphate (*khari*) and carbonate (*saji*), accumulate in the soil of many areas in India where the climate is dry, giving rise to the alkaline efflorescence known as *reh*, which renders large areas quite sterile. Both the sulphate and carbonate are also prominent amongst the sodium compounds in the brine of the Rajputana salt lakes. Carbonate of soda occurs in considerable quantity in the water of the Lonar lake and in the lakes of Eastern Sind.

Alkaline soils.

A general account of the alkaline deposits (*reh, saji mati, khari*) used in India is to be found in the *Agricultural Ledger*, No. 5 (Reporter on Economic Products, Calcutta, 1902) and in J. W. Leather's 'Investigations on Usar Land' (Allahabad, 1914).

Official figures for production are not available. Even the returns of production of *khari* in the province of Bihar and Orissa, as given in previous reviews, are only available for 1923-24 (12,551 tons) and 1924-25 (8,227 tons). Such returns have been discontinued since the removal of official supervision exercised over the occasional production of dutiable common salt in refining processes.

Usually sodium carbonate predominates, but in many places sodium sulphate is the chief constituent. In Bihar the districts producing are Champaran, Muzaffarpur and Saran. *Saji mati* is also recovered at the present time from many parts of the United Provinces. Benares, Azamgarh, Jaunpur and Ghazipur between them are said to send 2,000 tons a year to Calcutta and it is also recovered from the neighbourhood of Cawnpore, Hathras, Muttra, Shahjahanpur and Dehra Dun. According to information kindly supplied by Imperial Chemical Industries a specimen from Cawnpore recently on sale in Calcutta carried 27·02 per cent. sodium carbonate, 4·28 per cent. sodium bicarbonate and 33·98 per cent. sodium sulphate, while one from Dehra Dun had 31·44 per cent. sodium carbonate and 6·55 per cent. sodium bicarbonate. An idea of the extent of the deposits in the United Provinces may be gathered from a paper

by E. R. Watson and K. C. Mukerjee,[1] where also several analyses of the soils and recovered products may be found. By what is probably an optimistic method of extrapolation they calculated 'that 7,321,000 tons of crude soda, containing 4,888,000 tons Na_2CO_3 could be obtained annually from the visibly efflorescent areas in this province.'

The method of extraction usually adopted is very similar to that used in the recovery of saltpetre.

Saji mati is used for soap making and for washing clothes. The *khari* variety, containing more sodium sulphate, is largely used by tanners, who claim that it produces a softer leather than treatment with pure materials.

Soda occurs in the bed of a remarkable lake in Berar, the Lonar lake, (19° 59′ ; 76° 34′) situated in a depression in the Deccan trap.

Lonar Lake.

The depression is nearly circular, about a mile in diameter and 300 feet deep ; at the bottom there is a shallow lake of saline water, which varies in size and density according to the season of the year, and rests on a stratum of alkaline mud of unknown depth. In 1910 (no later estimates are available) the lake water contained about 2,000 tons and the upper five feet of mud about 4,500 tons of alkali, reckoned as sodium carbonate.[2] From the lake water products of varying degrees of purity are recovered by crude fractional crystallisation, the best of them, *dalla*, having a composition approaching that of the natural mineral urao, Na_2CO_3, $NaHCO_3$, $2H_2O$. During the quinquennium the production has been very small—in 1924, 20 tons ; in 1925, 35 tons ; in 1926, 100 tons. The company working the concession went into liquidation in 1927, and production stopped. The rights in the lake were auctioned for Rs. 700 for 1929, to a new lessee. Even in its local market the product seems unable to compete with imported soda ash.

Soda is collected during the hot weather from a large number of alkaline lakes or '*dhands*' in the Indian state of Khairpur and

Alkaline lakes of Khairpur and Sind.

in eastern Sind. These have been described by G. de P. Cotter,[3] and an account of them, condensed from Dr. Cotter's memoir, was

[1] *Jour. Ind. Industries and Labour*, Vol. II, p. 13 (1922).
[2] T. H. D. La Touche and W. A. K. Christie ; *Rec. Geol. Surv. Ind.*, Vol. XLI, p. 280 (1912).
[3] *Mem. Geol. Surv. Ind.*, Vol. XLVII, Part 2 (1923).

given in the quinquennial review for 1919 to 1923. The lakes are situated in depressions among the sand hills and their waters contain varying amounts of carbonate, chloride and sulphate of sodium. On evaporation there is obtained a crude form of urao, Na_2CO_3, $NaHCO_3$, $2H_2O$, locally known as *chaniho*. According to Dr. Cotter its principal use is in the preparation of light biscuits, but it is also used for washing clothes, in hardening treacle, in soap making, and in the preparation of *goorakho* tobacco.

TABLE 135.—*Production of Chaniho in Khairpur State during the years 1924-25 to 1928-29.*

Year.	Production in tons.	Number of '*dhands*' producing.
1924-25	551	17
1925-26	689	15
1926-27	1,040	27
1927-28	972	21
1928-29	502	14
Average	751	19

In the Nawabshah district in Sind, 133 tons were recovered in 1923-24, 130 in 1924-25, 111 in 1925-26, 137 in 1926-27 and 148 tons in 1927-28. A large proportion of the *chaniho* recovered is exported from Karachi, mainly to Arabia.

Table 136.—*Value and destination of exports of Chaniho from Karachi in the years 1926-27 to 1928-29.*

—	1926-27	1927-28	1928-29
	Rs.	Rs.	Rs.
Foreign Countries—			
Aden and Dependencies . .	56,297	67,417	68,636
Ceylon	2,235	1,872	2,446
Zanzibar and Pemba . . .	236	26	34
Bahrein Islands	150	75	255
Somaliland Protectorate . .	--	558	.
Maskat Territory and Trucial Oman	1,211	2,618	1,405
Other Native States in Arabia .	453	8,278	16,784
Persia	1,439	1,151	1,677
Italian East Africa . . .	1,728	5,392	3,488
Egypt	—	—	162
French Somaliland . . .	—	—	16
Coast Ports—			
Bombay, chief port . . .	17,477	15,238	17,763
Bombay, other ports . . .	33,238	750	18,854
Madras, other ports . . .	28,022	14,289	23,807
Baluchistan Agency Tracts . .	100	72	92
Cutch	2,230	2,177	2,515
Kathiawar	19,199	20,816	19,752
Goa	584	305	430
Diu	24	—	—
Gaekwar's Territory . . .	—	--	588
TOTAL .	**1,64,623**	**1,41,034**	**1,78,704**

As a potential source of sodium salts other than the chloride, the Sambhar salt lake in Rajputana may be mentioned. The lake dries up nearly every year, but the brine formed when it fills in the rainy season has a fairly uniform composition from year to year. The residue on evaporation contains about 86 per cent. sodium chloride, 10 per cent. sodium sulphate and 4 per cent. sodium carbonate. In the mother liquors from salt manufacture the percentage of sulphate and carbonate are, of course, much greater. As the upper 12 feet of the lake mud contain some 50 million tons of sodium chloride, it is reasonable to conclude that there are several million tons of sodium sulphate and carbonate similarly stored, but the time of their economic exploitation is not yet.

Sambhar Lake.

Manufacture of soda from salt.

The sensational development of the quinquennium was the building of a large soda factory in the Indian state of Dhrangadhra on the Little Rann of Cutch. The Shri Shakti Alkali Works was intended to produce annually the equivalent of 22,000 tons of sodium carbonate by the ammonia soda process. Salt is, of course, available in unlimited quantities on the Little Rann, and limestone was obtained from Jasdan. An attempt to get the works into operation in July, 1928, was unsuccessful, and subsequent efforts have proved similarly abortive.

Magadi Soda Company.

The Magadi Soda Company went into liquidation soon after the commencement of the period covered by this review. The company had a plant at Budge Budge near Calcutta for the manufacture of caustic soda from sodium carbonate imported from the Magadi lake in Kenya Colony, where huge natural deposits occur. The works at Budge Budge are closed down, and it is at present unlikely that the industry will be revived. Heavy freight on suitable limestone was one of the factors that made it difficult for the company to compete with imported caustic soda.

Imports.

The imports of alkalies for the years 1924 to 1928 are given below.

TABLE 137.—*Imports of Alkalies.*

	Sodium carbonate.	Caustic soda.	Sodium bicarbonate.
	Tons	Tons	Tons
1924	42,123	5,202	5,948
1925	38,822	6,496	4,601
1926	49,077	7,897	5,928
1927	50,568	8,711	5,133
1928	57,448	8,882	5,410

The imports of sodium carbonate are increasing rapidly, due mainly to appreciation by the ordinary washerman that its efficacy exceeds that of crude *saji mati.*

Steatite.

[E. L. G. Clegg.]

One of the most widely distributed minerals in India is steatite either in the form of a coarse potstone—so called on account of its general use in making pots, dishes, etc.—or in the more compact form suitable for carvings, and in its best form, suitable for the manufacture of gas-burners. Cooking utensils of steatite are much in request by high-caste Hindus, since they can be purified, after use, by fire and communicate no unpleasant taste to food. There is a trade of undetermined extent in nearly every province, but it is in most cases impossible to form even a rough estimate of its value.

Within recent years steatite bricks have come into increasing use as a special type of refractory, where resistance to corrosion, especially by highly alkaline slags, is the primary consideration; they are also used in the Wagner alkali smelting furnace at the recovery end of a paper mill.

An exhaustive account of the Indian occurrences of steatite was published by Mr. F. R. Mallet in the *Records, Geological Survey of India*, Vol. XXII, part 2 (1889); and a later note[1] adds further details with regard to the deposits in the Minbu district, Burma. In 1911-12, Mr. C. S. Middlemiss[2] discovered a large deposit of steatite of very fair quality near Dev Mori in Idar State, Bombay Presidency, associated with various other magnesian minerals (actinolite, magnesite, serpentine and asbestos). He estimates that bed of steatite to be over 1 mile long with a width of over 200 feet and a vertical dip. On this basis it is calculated that 2 million tons are obtainable in the first 20 feet from the surface. Dr. A. M. Heron has collected notes on some hitherto undescribed steatite deposits in Jaipur State, Rajputana.[3] The principal localities are: Dogetha, 2½ miles N.E. of Raialo; Gisgarh; and Morra. In the last mentioned area one of the beds measures 25 feet in thickness, and pockets of steatite extend over a distance of 5 miles.

The steatite deposits on the north side of the Marble Rocks in the Jubbulpore district form pockets in the dolomite of the gorge. They were formerly worked by native methods with a small annual

[1] H. H. Hayden; *Rec. Geol. Surv. Ind.*, XXIX, p. 71 (1896).
[2] *Ibid.*, XLII, p. 52 (1912).
[3] *Ibid.*, XLIII p. 21 (1913).

production, but are now held on mining lease by Messrs. Burn & Company who have erected a grinding mill in their pottery works at Jubbulpore and are converting their steatite into powder; deposits at Gowari and Lalpur on the south side of the Narbada have been secured by the Bombay Mining and Prospecting Syndicate. Steatite is also reported to occur in considerable quantity in a hill not far from Rupaund, a few miles from the Katni—Bilaspur line of the Bengal Nagpur railway. The annual output from the Central Provinces during the period under review averages 1,201 tons valued at Rs. 27,815.

The Burmese production comes from the Pakokku Hill tracts and was used for pencils. In former years steatite was also produced in the Minbu and Myitkyina districts. The mines in the Minbu district have been described by Sir Henry Hayden[1] and are situated some 30 miles west of Hpa-aing. The veins of the mineral are very inconstant and ramify through dark green serpentine, expanding occasionally to 8 or 9 inches across. The colour is green and the quality good. The absence of production is said to be due partly to the gradual replacement of the steatite pencil by pen and paper and partly to the exhaustion of the deposits.

Mr. A. Ghose opened up the steatite deposits at Muddavaram and Musila Cheruvu near Betamcherla in the Kurnool district, and took out a mining lease in 1912. A market was obtained in America and on 158 tons exported in 1913, the prices obtained ranged from £7 for 'nugget' steatite to £14 per ton for block steatite, *c.i.f.* New York or European ports, most of the output of that year being white steatite from Musila Cheruvu. The larger portion of the steatite of this locality is green, and has fetched a price of £10 a ton. At Muddavaram the steatite is ivory white associated with quartzose rock and magnesite and is suitable for small articles such as gas-burners. The output in 1914, however, fell to 210 tons, in 1915, to *nil* and in 1916, 1917, and 1918, to just over 10 tons each year; during the period under review it has all but ceased. A small output is also reported from Nalgenda and Nirmal in Hyderabad State.

Such figures as are available for the output of Indian steatite are summarised in Table 138. The values assigned to the mineral vary between very wide limits, and although this is no doubt partly due to differences in the value of the product, according to

[1] *Rec. Geol. Surv. Ind.*, XXIX, pp. 71-76 (1896).

TABLE 138.—*Production of Steatite in India during the years 1924 to 1928.*

	1924		1925		1926		1927		1928		Average.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.	Rs.	Tons.	Rs.	Tons.	Rs.	Tons.	Rs.	Tons.	Rs.	Tons.	Rs.
Bihar and Orissa—												
Mayurbhanj	67	6,200	90	8,350	65	6,900	67	6,300	80	7,300	74	7,010
Nilgiri	..	3,500	..	..	..	..	..	..	..	..	..	(a)
Santal Parganas	..	..	..	..	..	..	110	1,654	..	..	(a)	(a)
Seraikela	18	1,000	26	1,400	11	600	19	1,060	15	840	18	980
Singhbhum	64	3,359	59	3,539	2,648	29,742	271	16,839	346	7,706	678	12,237
Burma—												
Pakokku Hill Tracts	7	1,956	3	800	17	5,808	..	..	..	..	(b) 9	2,855
Central India—												
Bijawar	221	2,[illegible]	202	1,920	208	1,972	202	1,920	162	6,600	199	2,914
Central Provinces—												
Bhandara	..	..	333	13,590	..	..	250	10,000	..	..	(c) 294	11,750
Jubbulpore	1,675	17,597	1,287	70,799	890	16,439	870	10,960	1,284	23,281	1,201	27,815
Madras—												
Karnul	4	245	4	244	3	210	..	..	..	..	(b) 4	233
Nellore	1[illegible]	6,538	82	5,724	65	2,411	87	3,917	49	2,331	78	5,184
Salem	804	19,745	713	16,697	480	12,549	795	19,438	164	6,940	591	25,074
Mysore	56	120	101	303	81	243	68	204	88	264	78	227
Rajputana—												
Jaipur	..	..	5,514	70,000	5,074	64,200	2,206	30,000	3,228	65,849	(d) 4,005	57,512
United Provinces—												
Hamirpur	37	8,050	31	7,040	73	8,686	8	760	119	8,629	54	6,633
Jhansi	18	864	76	770	54	500	100	1,680	4	330	50	829
TOTAL	**3,073**	71,337	**8,526**	2,01,086	**9,674**	1,50,260	**5,053**	1,04,732	**5,539**	1,30,070	**7,333**	1,61,253
Total value in sterling		£5,132 (£1 = Rs. 13·9)		£15,119 (£1 = Rs. 13·3)		£11,213 (£1 = Rs. 13·4)		£7,816 (£1 = Rs. 13·4)		£9,706 (£1 = Rs. 13·4)		£9,797

(a) Not taken into average.
(b) Average of three years.
(c) Average of two years.
(d) ,, ,, four ,,

the use to which it is put, yet some of the figures are probably but rough estimates. During the period under review figures for the total production and value of steatite in India have varied between 3,073 tons valued at Rs. 71,337 in 1924, to 8,526 tons valued at Rs. 2,01.086 in 1925, the average production being 7,333 tons valued at Rs. 1,61,253. During the previous quinquennium the average production was 6,079·1 tons valued at Rs. 89,854. The increase in value of the steatite produced is practically confined to that from the areas of Jaipur, Salem and Jubbulpore—the three largest producers.

Sulphur, Sulphuric Acid and Soluble Sulphates.

[E. H. PASCOE.]

Occurrence of sulphur.

Small quantities of sulphur are obtainable on the dying volcano of Barren Island in the Bay of Bengal, in the state of Kalat in Eastern Baluchistan, and on the Koh-i-Sultan and neighbouring volcanoes in Seistan and Eastern Persia. The Kalat sulphur mine near Sanni, which was formerly worked to some extent, was recently examined and the available sulphur estimated at 10,000 tons[1]; this is a conservative estimate, but even if the actual amount be several times greater, the deposit cannot be regarded as of serious potential value, since it represents little more than a year's supply.

Utilisation of sulphides.

India is likely, therefore, to be ultimately dependent for her acid on by-products from the reduction of metallic sulphides. In a previous review (*Rec. Geol. Surv. Ind.*, Vol. LII, page 321) it was reported that a scheme was on foot for the erection of a plant at Jamshedpur to treat the zinc concentrates of Bawdwin. The projected initial capacity of the plant was to be some 30,000 tons annually, but as a cheap supply of acid would be the key to many industries, there is no doubt that a very much larger output would be readily absorbed. The absence of such industries was seriously felt during the war. Thus the average annual value of imported bleaching materials alone during the five years 1914-18, was £88,709; for this import, formerly brought from Europe, India was dependent on Japan. The average value of bleaching powder annually imported between 1924 and 1928, was more than £52,000. The abandonment of the project referred to above has, unfortunately, pushed

[1] G. de P. Cotter; *Rec. Geol. Surv. Ind.*, L. p. 137 (1919).

into the future the possibility of any considerable advance towards making India self-contained in the matter of the more essential chemical manufactures.

Importation of sulphur.

A considerable amount of acid is already manufactured in India, but the industry is dependent entirely on imported sulphur. This used formerly to come from Sicily, but from 1917-18 to 1919-20, most of India's imports were derived from Japan. In 1920-21, Italy began to regain her former place, and maintained it during the quinquennium under consideration; increasing quantities are coming from Germany. The imports of sulphur during the five years 1924 to 1928, are shown in Table 139 and averaged 15,788 tons annually, valued at Rs. 15,74,014, as compared with an annual average of 8,469 tons valued at Rs. 14,35,853 for the period of the previous review.

TABLE 139.—*Imports into India of Sulphur, Sulphuric Acid, Ammonium Sulphate, Ammonia and Salts thereof, during the years 1924 to 1928.*

Year.	Sulphur.	Sulphuric acid.	Sulphate of ammonia.	Ammonia and salts thereof (anhydrous or otherwise).
	Tons.	Tons.	Tons.	Tons.
1924	13,763	195	277	1,144
1925	12,337	27	1,132	1,118
1926	17,658	22	5,793	1,273
1927	17,957	49	2,755	1,758
1928	17,227	295	14,188	1,471
TOTAL .	**78,942**	**588**	**24,145**	**6,764**
Average .	*15,788*	*118*	*4,829*	*1,353*

Imports of sulphuric acid.

The average annual import of sulphuric acid was 118 tons only valued at Rs. 44,344 as compared with 182 tons valued at Rs. 1,15,905 during the previous five years, 396 tons valued at Rs. 1,14,585 during the quinquennium 1914 to 1918, and 3,188 tons valued at Rs. 5,86,305 during the quinquennium 1909 to 1913. This decrease in imports of sulphuric acid is due to the increasing production of this chemical at numerous plants in India.

Production of sulphuric acid.

The acid as manufactured at different plants varies in strength from 65 to 95 per cent. H_2SO_4, according to the purposes for which it is required. The data of production available have accordingly been reduced to the uniform basis of 100 per cent. acid, and are summarised in Table 140.

TABLE 140.—*Production of Sulphuric Acid in India during the years 1924 to 1928.*

(Statute tons in terms of 100 per cent. acid.)

Provinces.	1924	1925	1926	1927	1928	Total for 1924-28
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Bengal	5,616	5,248	5,288	6,604	6,550	29,306
Bihar and Orissa . . .	8,627	10,525	11,603	13,504	9,342	53,601
Bombay	3,453	4,347	4,230	3,102	2,479	17,611
Burma	4,551	5,241	5,436	6,699	7,626	29,553
Madras	1,017	624	1,349	1,106	1,651	5,747
Punjab	221	239	236	307	398	1,401
United Provinces . . .	771	841	827	1,080	1,390	4,909
TOTAL .	24,256	27,065	28,969	32,402	29,436	142,128

During the four years 1919-22, the annual production was a little under 12,000 tons, but in 1923, the production jumped to 17,127 tons of 100 per cent. acid. This jump was mainly due to the increased recovery of by-product ammonia as ammonium sulphate at the coking plants, iron and steel works, and collieries in the provinces of Bengal and Bihar and Orissa. From Table 140 it will be seen that the quinquennium under consideration witnessed a still further increase in the output of the acid which in 1927, reached the record figure of 32,402 tons. The production of sulphuric acid in Bihar and Orissa is mainly for the manufacture of ammonium sulphate, as will be seen from the fact that the total ammonium sulphate produced in this province during the quinquennium reached the high figure of 52,725 tons.

Producers of sulphuric acid.

The producers of sulphuric acid are as follows, the figures being the total production of acid at 100 per cent. during the period under review :—

	Tons.
Bengal—	
D. Waldie & Co., Konnagar	5,807
Bengal Iron Co., Kulti	4,637
Bengal Chemical and Pharmaceutical Works, Calcutta .	2,777
Dr. Bose's Laboratory, Calcutta	1,526
The Indian Iron & Steel Co., Burnpur	14,559
Bihar and Orissa—	
Tata Iron & Steel Co., Jamshedpur	41,969
Burrakur Coal Co., Loyabad	1,593
East Indian Railway Colliery, Giridih	1,288
Bararee Coke Co., Ltd., Jamadoba	2,883
Jharia Sulphuric Acid Co., Lodna	5,868
Burma—	
Burma Chemical Industries, Rangoon	29,553
Bombay—	
Eastern Chemical Co.	12,186
Dharamsi Morarji & Co.	5,425
Madras—	
Cordite Factory, Nilgiri Hills	2,022
Other producers	3,725
Punjab—	
Several small producers	1,401
United Provinces—	
Krishna & Co.	250
Other producers	4,059

This wide distribution of sulphuric-acid manufacturing plant throughout India is a healthy sign of growing activity in chemical industries in the country, though, as might be expected, the objects of manufacture are very varied. Thus all the producers in Bihar and Orissa, and the Bengal Iron Company in Bengal, manufacture acid for their own ammonia by-product recovery plants; the Burma Chemical Industries manufacture chiefly for the refining of petroleum products in the Burmese oil industry; and the Nilgiri Cordite Factory produces for the manufacture of explosives. All the other producers may be taken as manufacturing for general chemical purposes.

The statistics of production of ammonium sulphate are given in Table 141, from which it will be seen that India produced 78,593 tons during the quinquennium, against 21,707 tons during the previous period.

Production of ammonium sulphate.

TABLE 141.—*Production of Sulphate of Ammonia in India during the years 1924 to 1928.*

—	1924	1925	1926	1927	1928	Total
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Bengal	4,754	4,607	4,529	5,919	6,059	25,868
Bihar and Orissa . . .	9,596	9,582	11,609	12,588	9,350	52,725
TOTAL .	14,350	14,189	16,138	18,507	15,409	78,593

Producers of ammonium sulphate.

The principal producers were as follows, the figures being the total production during the quinquennium:—

	Tons.
Bengal—	
The Bengal Iron Co., Ltd.	7,465
The Indian Iron & Steel Co., Ltd.	17,201
The Oriental Gas Co., Ltd.	1,202
Bihar and Orissa—	
The Tata Iron & Steel Co., Ltd.	38,799
The Bararee Coke Co., Ltd.	4,417
The Burrakur Coal Co., Ltd.	3,516
Jharia Sulphuric Acid Co., Ltd.	2,274
East Indian Railway Colliery, Giridih	2,173
The Eastern Coal Co., Ltd.	1,546

Ammonium sulphate is, of course, a valuable fertiliser for certain crops. During the preceding quinquennium the larger proportion of the Indian production was exported, mainly to Ceylon and Java, but exports during the five years 1924-28, amounted to less than a third of the total output; the countries which received the greater portion of the exports between 1924 and 1928, were Ceylon, Japan, Spain and Java.

Exports of ammonium sulphate.

TABLE 142.—*Exports of Ammonium Sulphate from India during the years 1924 to 1928.*

Year.	Quantity in tons.
1924	8,884
1925	8,376
1926	1,309
1927	6,718
1928	13
TOTAL	25,330
Annual average	*5,066*

These exports are nearly balanced by large and increasing imports totalling 24,118 tons, of which over 11,000 tons were imported during 1928. These supplies were supplemented by increasing imports of calcium cyanamide (including nitrolim) to which the following figures refer:—

Imports of nitrogenous salts.

Year.	Tons.
1924	1,450
1925	690
1926	1,204
1927	2,0[illegible]
1928	2,7[illegible]

Reference may also be made here to the recorded imports of ammonia and salts thereof summarised in Table 139, giving an annual average of 1,353 tons, against 824 tons for the previous five years, and utilised for general industrial purposes.

Sulphates of iron and copper.

For many years the pyritous deposits in India have been turned to account for the manufacture of soluble sulphates of iron and copper. The case of alum has been referred to already (*supra*, page 314), and with the alum, which was formerly obtained in quantity from the decomposed pyritous shales at Khetri and Singhani in Rajputana, copperas and blue vitriol were also obtained. No statistics are, however, available with regard to the history of these industries, which have had to give way to the importation of cheap chemicals from Europe, the imports of alum and copperas being considerable. Small quantities of copperas, varying from 3 to 15 cwts. are reported to have been obtained between 1925 and 1928, from the Khardang mine in the Ladakh *tehsil* of Kashmir.

MGIPC—M—VIII-4-20—14-10-30—950.